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Science Policy Study—Hearings Volume 16
RESEARCH FUNDING MECHANISMS

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HEARINGS

BEFORE THE

TASK FORCE ON SCIENCE POLICY

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

SECOND SESSION

MARCH 12, 13, 19, 20, 1986

[No. 112]

Printed for the use of the
Committee on Science and Technology

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RESEARCH FUNDING MECHANISMS

WEDNESDAY, MARCH 12, 1986

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to notice, at 8:30 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. Fuqua. Good morning. This morning we begin the sessions on research funding mechanisms.

During the course of the hearings, the task force is going to examine an important aspect of our national science policy, and that is, how the Federal Government provides funds to organizations and individuals for the purpose of conducting scientific research.

Over the past 30 years, there has been a gradual narrowing of the way funding mechanisms are used to the point that we are at today. The Federal Government relies very heavily on a single type of award, the individual project grant, and the various mechanisms currently used to support scientific research have many advantages. Some scientists, however, feel that the system restricts investigations to certain types of research and there are scientists who further claim that the system involves a disproportionate amount of effort and paperwork.

It has also been claimed that the administrative burden of reviewing proposals and the requirements for personal financial disclosures by reviewers have increased to the point where a growing number of scientists are reluctant to serve as reviewers. All of these points suggest that the time has come to question whether the current way we fund science research in this country should be modified to more adequately meet our research needs.

In order to gain perspective on how Federal funding research has developed over the past several decades, the task force commissioned the GAO to review the study of Federal funding mechanisms in support of research and to assess those mechanisms, and the result of that study will provide the basis for this in the following 3 days of hearings.

GAO has prepared a very excellent report of their findings and we welcome Ms. Sarah Frazier, Associate Director of Resources, Community and Economic Development Division of the General Accounting Office, who is with us today to present the results of the GAO's finding.

Ms. Frazier, we would pleased to hear from you at this time.

STATEMENT OF SARAH P. FRAZIER, ASSOCIATE DIRECTOR, RESOURCES, COMMUNITY AND ECONOMIC DEVELOPMENT DIVISION, U.S. GENERAL ACCOUNTING OFFICE, WASHINGTON, DC; ACCOMPANIED BY DR. MARK V. NADEL, GROUP DIRECTOR SCIENCE AND TECHNOLOGY GROUP, AND JOHN PERHONIS, ILENE POLLACK, AND CATHRYN WELDON, SCIENCE AND TECHNOLOGY GROUP, U.S. GENERAL ACCOUNTING OFFICE, WASHINGTON, DC

Ms. FRAZIER. Thank you, Mr. Chairman.

Mr. Chairman and members of the committee, we are pleased to be here today to discuss the mechanisms used by the major Federal funders of university research as described in the two reports that we have just issued. I have with me today the individuals who have performed much of the work we will discuss. On your left are Ms. Cathryn Weldon and Mr. John Perhonis, who cataloged the funding mechanisms used by the major Federal funders of university research. On your right are Ms. Ilene Pollack, who played a key role in preparing the second report, which assesses the funding mechanisms, and Dr. Mark Nadel, who has overall responsibility for our work in this area. I would like to give you a summary of our statement, the whole of which has been submitted for the record.

As you know, and as you have said, the United States relies primarily on its universities for the performance of basic research. Within the last decade, concern has grown that the current means of funding research may not be adequate to provide the continuity and stability, the modern facilities and equipment, and the human resources needed for universities to maintain this vital role in the Nation's research efforts.

In presenting our statement, I will speak separately about the two reports and then summarize the main points briefly. From time to time I will refer by page number to graphics that are included in the copy that you have of our statement.

First, I would like to review what we mean by a Federal funding mechanism. These are categories of Federal financial support that enable Federal agencies to provide either direct support of scientific research or indirect support through the research infrastructure.

Direct support, the first broad category, includes support for specific research projects under the direction of a single university researcher and for a specific period of time. This type of direct support is called individual project support. In addition, direct support can be given to programs where there may be one or more principal investigators working toward a common objective, or to a research center, where projects are coordinated into a coherent program in a particular field of interest.

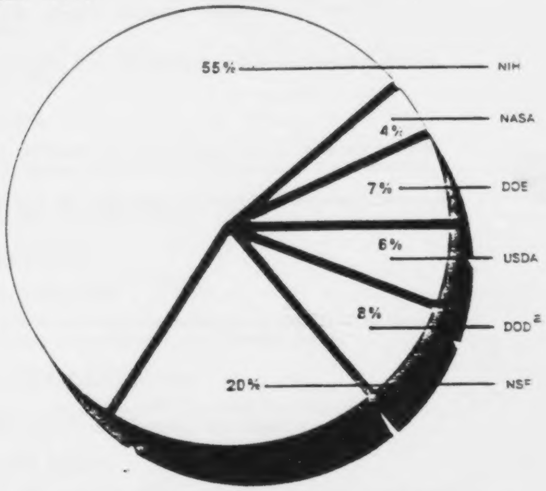
We refer to the second broad category of funding mechanisms as support for the research infrastructure or indirect support. Such funding is provided directly for training, for the purchase of major research equipment for instrumentation, and construction of buildings, or for general institutional support.

The objectives of our first report, "Federal Funding Mechanisms in Support of University Research"—the thicker of the two—were to describe how frequently the different types of Federal funding mechanisms were used by Federal agencies and to show how this use has changed over time. The data in our report is current through fiscal year 1984. It was collected from six Federal agencies: NIH, NASA, the Department of Defense, the National Science Foundation, and the Departments of Energy and Agriculture. In that year, these agencies funded 90 percent of the Federal support for scientific research performed at universities and colleges.

Figure 1 on page 3 of our statement shows these six agencies in the relative proportion of such funding that each provides.

Figure 1:

Percent of Obligations for University Research by Federal Agency (Fiscal Year 1984)



[a]Includes only basic (DOD 6.1) part of DOD's funding of university research.

Source: GAO, based on data reported by six agencies.

In fiscal year 1984, these six agencies awarded about 89 percent—or $4.5 billion—of their extramural research funds through direct funding mechanisms, the first broad category. Of this amount, about $3.4 billion—or 71 percent of all support—was awarded through the individual project award funding mechanism.

Direct support awarded to programs and to centers accounted for about $900 million, or about 18 percent of total agency obligations. As might be expected, these latter types of awards were often for multidisciplinary research programs and tended to be larger, on the average, and were awarded for a longer period of time.

Indirect funding mechanism awards supporting the research infrastructure accounted for about 11 percent of the total research funding in fiscal year 1984.

Figure 2 on page 4 of our statement further describes the funding mechanisms and shows the relative percentage of use of each.

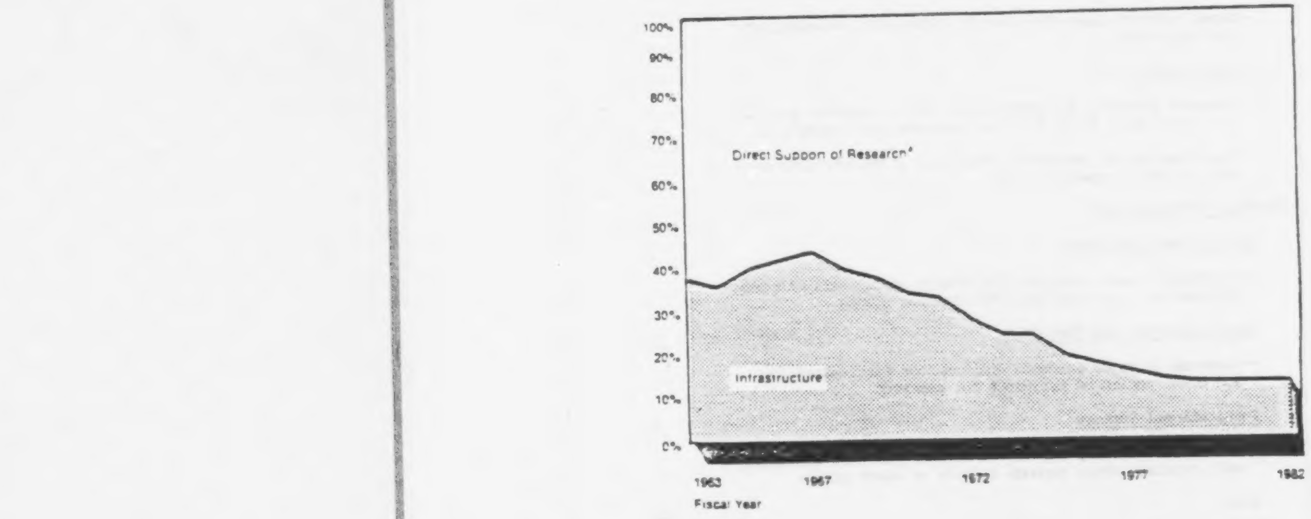
Figure 2:
Federal Funding Mechanisms

DIRECT SUPPORT OF RESEARCH	Percent of total support
Individual Project Support	71
—support for an individual researcher called a principal investigator. Support may include funding for graduate student assistants, equipment, travel, salaries, etc.	
—research in a discrete research area and of limited duration	
Program Support	9
—support for more than one principal investigator, each conducting research projects related to an overall objective	
—broad coherent area of research, often multi-disciplinary and long term	
Center Support	9
—research projects are coordinated into a coherent program in a particular broad field of interest at a university	
—core funding for equipment, facilities, and administrative unit called a research center	
RESEARCH INFRASTRUCTURE	
Special Training Needs	4
—scientific human resource development specifically through fellowships, traineeships, and training grants	
Major Equipment and Facilities	2
—purchase of major research equipment or instrumentation and construction of buildings for research	
Institutional Support	5
—usually unspecified support to enhance research capability and training, often through formula or block grants	
Total	100

Analyzing data collected by the National Science Foundation for the years 1963 to 1982, we also found the following trends in the use of funding mechanisms. Direct support of research has increased. As illustrated in figure 3 on page 8 of our statement, direct support has increased as a percentage of total research funds from 62 percent in fiscal year 1963 to 87 percent in fiscal year 1982

Figure 3:
Percent of Federal Scientific Research Obligations to Universities/Colleges by Funding Category (Fiscal Years 1963-1982)

Direct Support of Research vs. Research Infrastructure



^aMay include support for equipment as well as graduate assistantships as part of the costs of research projects.

Source: GAO, based on Federal Support data.

There has also been an increase in absolute dollars from $1.1 billion in 1963 to $2.2 billion in 1982, using constant 1972 dollars.

Support that is earmarked for the research infrastructure has decreased. Over the years, the percentage of total obligation supporting the research infrastructure has decreased from 38 percent in fiscal year 1963 to 13 percent in fiscal year 1982. There has also been a decrease in absolute dollars from $688 million in 1963 to $331 million in 1982.

Many award mechanisms that were used in the early 1960's, specifically to support the research infrastructure, have been discontinued. Lest this trend appear too dramatic, let me add that the research infrastructure is now also supported through the direct funding mechanisms of individual project program and center awards rather than through the previous forms of infrastructure support. For example, according to a budget official at the National Science Foundation, over $100 million of the National Science Foundation's funds provided to universities in fiscal year 1985, through the individual project support mechanism, was for equipment. Furthermore, in 1984, NSF funded 11,000 research assistantships through direct-support mechanisms.

Moving now to our second report, therein, our purpose was to assess the relative merits of different types of funding mechanisms for the performance of research. Specifically, we wanted to determine whether particular funding mechanisms help universities improve program quality and to examine whether two different types of funding mechanisms, individual project awards and center awards, had different impacts on the performance of research.

First we chose five university departments which, according to two national surveys of U.S. doctoral research programs, had shown improvement in program quality. The five were all located in the South: Emory University, the Georgia Institute of Technology, the University of Alabama at Birmingham, the University of Texas at Austin, and the University of Georgia.

We visited the schools to find whether their reputed success was attributable to any particular Federal funding mechanism. The common element reported to us was an explicit commitment by each university to improve its program and to do so through increases in internal and external funding, as well as personnel changes. In general, we did not find that the type of funding mechanism seemed to be a significant factor. That there was seed money—whether from governmental or private sources—was critical. All five university departments reported that they were able to leverage their seed money so that they could successfully compete for continuing Federal support.

To meet our second objective of examining whether two funding mechanisms had different impacts on the performance of research, we used a case study approach. For five different fields of science, we compared the university departments where researchers received individual project awards with those where center awards were made.

On page 12 of our statement, figure 4 shows the universities and the departments that we studied. We found that the adequacy and the availability of equipment, facilities, and technicians varied by field of science rather than by funding mechanism.

Figure 4:
Matched Pairs of Universities by Field of Science

Field of science	Center locations	Department locations
Mathematics	University of Wisconsin-Madison	University of Michigan
Space science	University of Chicago	University of Iowa
Artificial intelligence	Massachusetts Institute of Technology	University of Texas
Cell biology	Yale University	New York University
Plant sciences	Michigan State University	Cornell University

We found that scientists' perceptions were that stability of financial support was affected more by agency policy decisions such as decreases in the number of—or the average size of awards—rather than by the type of funding mechanism itself. However, 17 of 34 of those with individual project awards felt that funding gaps were a problem, while 21 of 29 researchers working in centers said they did not have a problem with funding gaps. Further, researchers at centers believed that the centers provided seed money to start research that would otherwise be unfunded and that center funding contributed to a sense of stability and continuity of support.

Scientists in centers proposed more research into new high-risk interdisciplinary areas and performed more research bridging two or more fields than those receiving individual project support. Additionally, we found that the administrative burden, as measured by the amount of time spent applying for awards or responding to award requirements after selection, varied more by field of science and agency requirements than by type of funding mechanism. On the average, scientists in fields that received awards from defense agencies reported spending more time in post-award activities than in pre-award activities, while the reverse was true for scientists whose awards were from civilian agencies.

Our reports contain much more detail on these matters, including a catalog of 84 funding mechanisms used by the six major Federal agencies in the past and currently to fund research to universities.

I would like to summarize briefly the main points that we make.

First, in fiscal year 1984, about three-quarters of the Federal obligation for university research was via individual project awards which in themselves evidenced considerable variation in size, duration, and objectives.

Second, in the same fiscal year, about 11 percent of Federal obligations were earmarked for the infrastructural needs of research.

From 1963 to 1982, Federal agencies have increasingly devoted a larger percentage of their funds to direct support of research. However, funds for direct support also provide for some infrastructural needs in the form of training, equipment, and indirect-cost reimbursement.

For improving the reported quality of university research programs, the particular funding mechanism played a lesser role than the university's commitment to improving the program and its ability to obtain funds from a variety of sources.

Last, for performance of research, scientists generally indicated that the field of science in which they worked had a greater effect on administrative burden and availability of infrastructure support than the particular funding mechanism. However, center researchers believed that their financial and resource support was more stable and that they were more likely to perform new research than researchers with individual project awards.

This concludes our statement, Mr. Chairman. We will be glad to answer any questions that you may have.

[The prepared statement of Ms. Frazier follows:]

United States General Accounting Office
Washington, D.C. 20548

FOR RELEASE ON DELIVERY
EXPECTED AT 8:30 A.M.
WEDNESDAY, MARCH 12, 1986

STATEMENT OF
SARAH P. FRAZIER, ASSOCIATE DIRECTOR
RESOURCES, COMMUNITY, AND ECONOMIC
DEVELOPMENT DIVISION
BEFORE THE
HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY
ON
FEDERAL FUNDING MECHANISMS
IN SUPPORT OF UNIVERSITY
RESEARCH

Mr. Chairman and Members of the Committee:

We are pleased to be here to discuss our two recently issued reports on federal funding mechanisms in support of university research. The first report describes the characteristics of funding mechanisms used by the major federal funders of university research and provides an inventory of those mechanisms.[1] The second report assesses selected federal funding mechanisms from the perspective of the recipients at the universities.[2] For our purposes, a "funding mechanism" is defined as a category of federal financial support for scientific research performed at and by universities. I will summarize each report separately.

---

[1] University Funding: Federal Funding Mechanisms In Support of University Research, GAO/RCED-86-53, February 13, 1986.

FEDERAL FUNDING MECHANISMS IN SUPPORT OF UNIVERSITY RESEARCH

The objectives of our first report, the inventory of federal funding mechanisms, were

--to describe the past and present federal funding mechanisms, including relative magnitudes of support, that federal agencies use to fund university research, and

--to describe the trends over time in federal agencies' use of funding mechanisms.

To prepare this report, we collected data for fiscal year 1984 from the six federal agencies that fund 90 percent of the support for scientific research performed at universities and colleges. These agencies, which obligated $4.8 billion for fiscal year 1984 for university research, are the National Institutes of Health (NIH), the National Science Foundation (NSF), the Department of Energy (DOE), the Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), and the U.S. Department of Agriculture (USDA). As figure 1 shows, the National Institutes of Health and the National Science Foundation provide over three-fourths of the total funds obligated.

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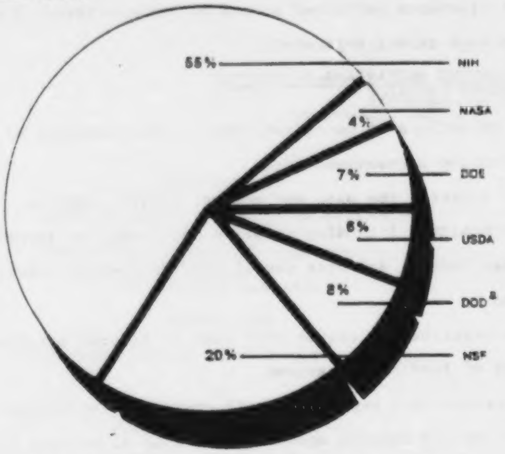
[2] University Funding: Assessing Federal Funding Mechanisms for University Research, GAO/RCED-86-75, February 7, 1986.

Figure 1:

Percent of Obligations for University Research by Federal Agency (Fiscal Year 1984)



[a] Includes only basic (DOD 6.1) part of DOD's funding of university research.

Source: GAO, based on data reported by six agencies.

Past and Present Funding Mechanisms

To address our first objective, we developed six categories of funding mechanisms that could be applied across agencies. These categories are based on literature review and advice from experts and are shown in figure 2. They fall into two groups--direct support and support of the research infrastructure. The agencies reported 84 different awards within these 6 categories.

Figure 2:
Federal Funding Mechanisms

	Percent of total support
DIRECT SUPPORT OF RESEARCH	
Individual Project Support	71
—support for an individual researcher called a principal investigator. Support may include funding for graduate student assistants, equipment, travel, salaries, etc.	
—research in a discrete research area and of limited duration	
Program Support	9
—support for more than one principal investigator, each conducting research projects related to an overall objective	
—broad coherent area of research, often multi-disciplinary and long term	
Center Support	9
—research projects are coordinated into a coherent program in a particular broad field of interest at a university	
—core funding for equipment, facilities, and administrative unit called a research center	
RESEARCH INFRASTRUCTURE	
Special Training Needs	4
—scientific human resource development specifically through fellowships, traineeships, and training grants	
Major Equipment and Facilities	2
—purchase of major research equipment or instrumentation and construction of buildings for research	
Institutional Support	5
—usually unspecified support to enhance research capability and training, often through formula or block grants	
Total	100

Three mechanisms that directly support research are the individual project award, the program project award, and the research center award. In fiscal year 1984, the six agencies awarded about 89 percent, or $4.3 billion, of their research funds through these three funding mechanisms. Three mechanisms which support research by providing funds for infrastructure are major equipment and facilities, special training needs, and general institutional support. These three mechanisms accounted for 11 percent, or $523 million, of the total obligations for fiscal year 1984.

It is important to note that these mechanisms can provide support for similar research needs. Funding mechanisms for the research infrastructure designate support specifically for research equipment and graduate student training; at the same time, direct support funding mechanisms also commonly provide some support for equipment and student training necessary to perform the particular research. In addition, the research infrastructure is supported through indirect cost reimbursements on research projects.

Direct Support: Individual Project Award

The funding mechanism receiving the most support by far is the individual project award. About $3.4 billion, or 71 percent of total support, was provided through this mechanism in fiscal year 1984. In general, this funding mechanism supports scientific research under the direction of a single university researcher who is issued an award competitively for a research proposal. There is wide variation in award amount—from an average award of $67,000 by NSF to an average award of $152,000 by DOE. Some awards are designated for specific recipients or purposes, such as for young investigators and for short-term, preliminary projects.

Direct Support: Program and Center Support

The second and third categories of direct support of research are for program projects and research centers. These categories accounted for about 18 percent of total agency obligations, or $900 million, in fiscal year 1984. Agencies reported that research performed under these mechanisms is often multidisciplinary and is related to a broader, more extensive research goal or program. They are longer in duration and larger in dollar size than are individual research projects. Project and center awards can be granted for up to 5 years and range from an average of $89,000 for a NASA program grant to an average of $3 million for a DOE center award.

Research Infrastructure

Of the three funding mechanisms that support the research infrastructure, institutional support received 5 percent of total funding, due mostly to USDA's formula awards; major equipment and facilities received 2 percent; and special training needs received 4 percent.

Funding Trends

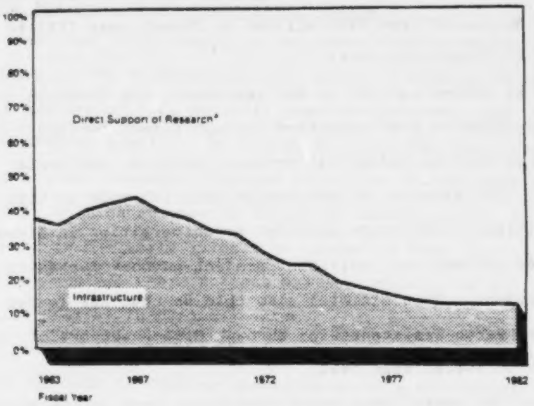
To describe the trends over time in federal agencies' use of funding mechanisms--our second objective--we used data collected by the National Science Foundation as presented in its annual publication, Federal Support to Universities, Colleges, and Selected Nonprofit Institutions. This publication describes federal funding from 1963 to 1982 by categories of support that we correlated with the six funding mechanisms we developed.

Direct Support of Research Has Increased

As figure 3 shows, federal funds in direct support of research--which includes individual project, program, and center support--have increased as a percentage of total research funds over the last two decades from 62 percent in fiscal year 1963 to 87 percent in fiscal year 1982. There has also been an increase in absolute dollars. Using constant 1972 dollars, direct support of research has increased from $1.1 billion in 1963 to $2.2 billion in 1982.

Figure 3: Percent of Federal Scientific Research Obligations to Universities/Colleges by Funding Category (Fiscal Years 1963-1982)

Direct Support of Research vs. Research Infrastructure



[a] May include support for equipment as well as graduate assistantships as part of the costs of research projects.

Source: GAO, based on Federal Support data.

Support of Research Infrastructure Has Decreased

The converse of the NSF trend data, of course, is that the percentage of total obligations supporting research infrastructure, which includes mechanisms specifically designated for major equipment and facilities, special training needs, and institutional support, has decreased over the same period, from 38 percent in fiscal year 1963 to 13 percent in fiscal year 1982. There has also been a decrease in absolute dollars. Using constant 1972 dollars, research infrastructure funding decreased from $688 million in fiscal year 1963 to $331 million in fiscal year 1982.

As we stated earlier in our testimony, the research infrastructure is also supported through direct funding mechanisms such as individual project, program, and center support. For example, an NSF budget official told us that over $100 million of NSF funds provided to universities in fiscal year 1984 through the individual project support mechanism was for equipment. This official also told us that NSF funded 11,000 research assistantships through direct support of research in fiscal year 1984.

Over the years, many award mechanisms used in the early 1960s specifically to support the research infrastructure have been discontinued. By the mid-1970s, most of the federal programs specifically for training, facilities, and institutional programs designated had been discontinued.

ASSESSING FEDERAL FUNDING MECHANISMS

Our second report assessed the relative merits of different types of funding mechanisms for performance of research. Our objectives were specifically

--to determine whether particular funding mechanisms play a role in helping universities improve program quality as perceived by the scientific community and

--to examine whether two different types of funding mechanisms--individual project awards and center awards--had different impacts on the performance of research.

The Role of Funding Mechanisms In Improving the Quality of University Science

To meet our first objective, we chose five university departments in the southeastern U.S. which, according to two national surveys of U.S. doctoral research programs, had improved program quality. We wanted to learn how they were able to improve their research programs after the federal government had largely eliminated special financial assistance for program improvement in the early 1970s. We wanted to know, in particular, whether their success was attributable to any particular federal funding mechanism.

In general, at the university departments we visited we did not find the type of funding mechanism to be a significant factor in improving program quality. Instead, the common element reported to us was an explicit commitment from the university to improve its program and to do so through increases in internal and external funding and through personnel changes.

According to department chairmen and others we interviewed, seed funding from either government or private sources was a prerequisite to program improvement. Two of the five university departments--the University of Georgia and the University of Texas--received institutional support through substantial

National Science Foundation Science Development grants in the late 1960s. The Science Development grant program was one of the broad institutional programs created in that decade to increase the number of institutions of recognized excellence in research and research education in the sciences. It was discontinued after fiscal year 1972. University officials at both schools agreed that the availability of these federal grants was a major factor in their program improvement strategy and enabled each department to attract excellent researchers, renovate research space, and purchase critical equipment.

The other three university departments--Emory University, the University of Alabama, and the Georgia Institute of Technology--sought and received seed funding from industrial sponsors, state appropriations, and the university itself. For example, Emory University provided $620,000 to its Department of Microbiology and Immunology to increase the number of tenured daculty. The university also agreed to renovate space for the department at a cost of over $1.5 million.

After the initial investment, all five departments were able to "leverage" that seed money into success in competing for continuing federal support.

The Role of Funding Mechanisms in the Performance of Research

We used a case study approach to meet our second objective--to examine whether two funding mechanisms had different impacts on the performance of research. Using five fields of science, we compared five university departments where researchers receive individual project awards with five university research centers. These are listed in figure 4.

Figure 4:
Matched Pairs of Universities by Field of Science

Field of science	Center locations	Department locations
Mathematics	University of Wisconsin-Madison	University of Michigan
Space science	University of Chicago	University of Iowa
Artificial intelligence	Massachusetts Institute of Technology	University of Texas
Cell biology	Yale University	New York University
Plant sciences	Michigan State University	Cornell University

We administered a questionnaire to 70 researchers to obtain their perception of the impact on the performance of research of individual project awards compared with center awards.

We assessed individual project awards and center awards against four factors that have the potential to affect the performance of research.

--Coverage of resource requirements.

--Stability of financial and resource support.

--Type of research supported.

--Administrative burden.

Coverage of resource requirements

The performance of research requires adequate resources--facilities, equipment, and people. Responses from scientists to questions on the adequacy and availability of such resource requirements varied by field of science rather than by funding mechanism. For example, in response to the question "Has the quality of research facilities changed since 1970," 28 of 36 scientists reported that the quality of facilities had increased or stayed the same since 1970. No scientists in plant sciences or artificial intelligence reported decreases. However, some scientists in each of the other fields reported decreases.

Stability of financial and resource support

Scientists generally consider stable financial and resource support, which reflects the continuity and duration of support, beneficial for conducting research. To determine the impact of the two funding mechanisms on the stability of support, we asked scientists about the effect of the cyclical nature of support, funding gaps, and award duration on the performance of research.

For the cyclical nature of support, scientists reported that factors other than the funding mechanisms, such as agency policy decisions, affected their ability to perform research. For example, we were told by scientists that NSF's decision to divide available funds for mathematics by subfields resulted in destablizing research environments for certain subfields and individuals.

Concerning the effects of funding gaps on research, in response to the question "Have funding gaps been a problem?", 21 of 29 researchers working in centers said they did not have a problem with funding gaps. However, 17 of 34 researchers with individual project awards agreed that funding gaps have been a problem. In addition, some scientists receiving center support told us that the informal sharing of resources possible under center funding contributes to stability of funding. They also believed that center funding provides seed money to start research that would otherwise be unfunded and that it can provide continuous support for technicians.

Although scientists receiving both types of funding expressed concern about award duration or continuity of support, scientists in most centers we studied believed they had a longer term commitment under the center awards than scientists receiving individual project awards.

Type of research supported

The type of research supported reflects the influence of funding availability on the ability to pursue new and different areas of research. To determine which mechanism more often supports innovative, high-risk, and interdisciplinary research, we asked scientists questions about their research.

Some differences in the types of research supported emerged between scientists with individual project awards and those with center awards. More scientists in centers than scientists in departments told us they proposed more research into new areas and performed research bridging two or more fields. Twenty-five out of 32 center scientists stated they proposed research into new areas, as opposed to 14 out of 33 department scientists.

Administrative burden

The administrative burden for researchers varied more by field of science and agency requirements than by type of funding mechanism. This factor can be measured by the amount of time spent in preaward activities, such as applying for awards, and postaward activities, such as responding to award requirements and reviewing proposals. Defense agency award requirements include more postgrant reporting, while civilian agency award requirements include more preaward reviews of proposed research. Accordingly, on the average, scientists in fields that receive awards from defense agencies, such as artificial intelligence, reported they spent more time in postaward activities than in preaward activities. Scientists in fields that receive awards from civilian agencies, such as plant science, reported spending more time in preaward activities.

SUMMARY

To briefly summarize the major points of our two reports:

--In fiscal year 1984, 89 percent of federal obligations for university research was in direct support of research, and 11 percent was specifically in support of infrastructural needs of research.

--The funding mechanism supporting individual research projects received almost three-quarters of federal obligations for university research. There is great variation in purpose and size among the six agencies' use of this funding mechanism.

--From 1953 to 1982, federal agencies have increasingly devoted a larger percent of their funds to direct support of research as opposed to research infrastructure. However, funds that provide direct support of research also provide for some infrastructural needs in the form of training, equipment, and indirect cost reimbursement.

--For improving the reported quality of university research programs, the particular funding mechanism played a lesser role than the universities' commitment to improving the program and its ability to obtain funds from a variety of sources.

--For the performance of research, scientists generally indicated that the field of science in which they worked had a greater effect on the degree of administrative burden and the adequacy and availability of facilities, equipment, and technicians than the particular funding mechanism. However, center researchers believed that they had more stability of financial and resource support and were more likely to perform innovative, high-risk, or interdisciplinary research than did researchers with individual project awards.

This concludes our prepared statement. We will be glad to answer any questions.

DISCUSSION

Mr. **Fuqua**. Thank you very much.

You mentioned in your statement that the administrative burden from researchers varied more by fields of science and agency requirements than the type of funding mechanisms, and I am wondering how that really worked among the scientists and which—did there seem to be a preference? Or a—you went on to say that the "DOD award requirements include more post-grant reporting, while the civilian agency awards requirements included more preaward reviews of proposed research."

So, I guess in the civilian agencies they wanted to know what your qualifications were, what you planned to do before the grant was awarded. The defense agency was more interested in what you found out, in the end—if I am paraphrasing it correctly.

Ms. **Frazier**. The monitoring activities for the defense agencies were more strenuous, if you will. The competitive process in the early stages for the civilian departments—to oversimplify—was, where there was additional emphasis, rather than—such as project reports and so on. Those were the things that the Defense Department tended to emphasize.

Mr. **Fuqua**. Well, you report that much of the 1969 to 1970 decline in research facility funding can be attributed to a change of Government policy away from direct Federal support of facilities toward other mechanisms such as subsidizing interest payments on loans and other mechanisms that were used, but do you have any information about this that would tell us how much research facility construction has been performed since 1969, using alternative mechanisms?

Ms. **Frazier**. Construction is the area that you are asking about? I am sorry.

Mr. **Fuqua**. Facilities. Yes.

Ms. **Frazier**. Facilities research. These folks have great knowledge of the detail and I will ask them to respond.

Mr. **Perhonis**. We don't have any information on that particular thing, that item, but we could, perhaps, provide you some. Particularly on the subsidy—the other mechanism that we mentioned there—in particular we do not have any information.

Mr. **Fuqua**. In the course of your study, did you collect data of that type? Or would it be burdensome to get that?

Mr. **Perhonis**. Not on that specific thing you are referring to there. Not that specific mechanism. We did not—we really did not concentrate on that as a mechanism per se, even though, you know, you can type it as that.

Mr. **Fuqua**. Would it be difficult to get that kind of information?

Dr. **Nadel**. Mr. Chairman, in a later report that we are preparing for this committee—and on which, I think, the hearings are scheduled in May—we have been collecting some information on university expenditures for research and we have collected some information on construction. Whether it has the extent of detail that you are asking for, I do not know, but we will certainly find out.

Mr. **Fuqua**. OK. Thank you.

You also noticed that an analysis for the causes of instability in funding and you found that factors other than the type of funding mechanisms were cited by the scientists and you noted that one such factor was like agency policy decisions as a main cause of instability. I am wondering what other causes did you find and, more specifically, about the congressional 1-year budget versus a multi-year funding authorization?

Ms. **Frazier**. Specifically, we found that, to some extent, the stability is, of course, a sense of perception on the part of the scientists, and that is why they felt those who were associated with the centers felt more comfortable. They felt that there was the ability there for the centers to provide support to tide them over during particular down times, and so that was something that aided them when they felt that there was, if you will, an infrastructure itself that would support them. But in terms of the policy decisions that were made by agencies when there were such instances as potential plans to decrease the number of awards that were being given for a multiyear period of time or change them from multiyear to single year, that was the instance when there was concern and considerable uncertainty regarding that feeling.

In specific, about multi-year or single-year awards, we did not do research to examine that specifically. We did try to identify what characteristics, and where there were agency variations that made concern among the scientists a feeling of instability.

Mr. **Fuqua**. These task force hearings have been going on for some time and one previous witness that I recall stated that they felt that some of the single-purpose grants had probably led to a decline in the overall quality of some of the work in universities—

and I am paraphrasing and I hope I am not misquoting what that person said—in effect, that where you were doing one specific project, compared to, say, a block grant to a science center that could have more multidisciplinary research going on, did you have any information or did you get into those kinds of areas? Or assess that area?

Ms. **Frazier**. We did not try to assess the effect in terms of quality. We did look at the differences between the center support or program support. And we found, from the case studies we did in the five universities in the South—which I listed earlier—that there was a direct sense that center support allowed a longer term and a more multidisciplinary approach and perspective, including providing some—as I mentioned earlier—continuity of support that would enable the individual researcher to be supported adequately between individual objectives and individual grants.

In terms of the effect of that on the quality, I think it perhaps would depend more on the nature of the issue being studied and, hence, one of the advantages of either a program or a center kind of orientation where multiple researchers could be, if you will, organized to pursue a specific objective as opposed to looking at an individual project.

So, in terms of actually assessing the quality, that we did not do. But there is an effect on the multidisciplinary nature and the ability to go after larger problems.

Mr. **Fuqua**. Mr. Lujan.

Mr. **Lujan**. Thank you, Mr. Chairman.

That is rather interesting, but it makes sense, I suppose, after you look at it. The institutional funding tends to lend it more stability than the individual grants.

There is one other thing that you mentioned that seemed to make a big difference and that is where universities are able to go out and get seed money—or get different sources of funding. I am wondering if that is because the seed money and the sources of funding are there, or if you could draw the conclusion that those universities that do go out and get seed money are more enthusiastic, do a better business of getting grants and because they are good at that, they are probably good at other things also?

It is kind of interesting. I just was thinking about, you know, in our business of raising funds and things like that, and they say, well, it is unfair if someone can raise more funds than the other for the competition. But that is all part of the organization. If you are well organized to raise funds and whatever, you are going to be better organized to do your other things.

Do you think that is probably the reason why those universities are more successful?

Ms. **Frazier**. What we found was, not necessarily the ability to raise funds or not, but intent to—or commitment, if you will, to improving the quality of the department or the program and, in so doing, in some instances, they brought in, the universities brought in, a new chairman of the department. And perhaps one of the qualifications for that individual was the ability to raise funds or the intent to do so—I do not know which—but, at any rate, we did find uniformly that there was commitment on the part of the university and then commitment on the part of the department which resulted in going after it.

Mr. LUJAN. Yes.

Ms. FRAZIER. So I guess maybe the necessary thing is that, certainly, the funds are not going to come to you unless you seek them out and aggressively doing so or actively doing so, and having a commendable plan for what you are going to do with those may have been what was necessary.

But in the various universities, those five universities, we found some relatively remarkable increases in size and funding of the departments themselves. Some of them had increased their size 7 or 8 times in terms of research funding that they had received and increased the size and the reputation, if you will, of their faculty and the number of postgraduates—students and graduate students—and the caliber of those students who worked with the university.

So the measures that one takes of the quality of the university or of the university department seemed to show up as areas that there was intent to make improvements.

Mr. LUJAN. Would you say, then, that those that do the good research and get the good grants and all of that, it is a direct result of their overall view? Because if they are enthusiastic about the fundraising or contacting industry or whoever would give them the seed money, that same enthusiasm then spills over into the enthusiasm for research.

Ms. FRAZIER. It seems that a commitment for doing good work results in their—perhaps results in their ability to get the funding to do more of that good work. And I would say that the attention on trying to improve the quality of the department perhaps—at least in these instances—reflected itself in receiving additional funds to do that work. So——

Mr. LUJAN. You could paraphrase that, then, as saying that "God helps those that helps themselves."

Ms. FRAZIER. Yes.

Mr. LUJAN. The Federal agencies help them who also help themselves.

Ms. FRAZIER. That is right.

Mr. LUJAN. Very good. One of our concerns—and we have been looking for ways of doing things and the chairman has been particularly active in that—is the funding of equipment and buildings, the whole infrastructure.

You mentioned that—at least, that is somewhere in your statement—that the U.S. Department of Agriculture, the USDA—let me see how you phrased that—"Due mostly to USDA's formula awards"—apparently that is a pretty good formula—can you tell us a little bit about that?

And if, in going through this and looking at all the formulas that—if, in fact, there are formulas by other agencies—that we ought to, as part of science policy, to look at this particular formula and see if it might not be applied towards others.

Ms. FRAZIER. I will give you some information and then, if you want more, I will refer to the experts here on this particular award mechanism.

That money is spent primarily for supporting the agricultural research centers that are set up around the country, and the formula nature of it accounts for the fact that that money is allocated to reflect, I believe, the population base in the area that is being serviced by those agricultural research centers. And so, the formula is a mechanism for assuring, if you will, equitable distribution and it is valuable to that extent.

It also, I think—because of the long-term nature of those awards, the continuity of it, the dependability of it—allows for some of the projects that go on to have a longer term characteristic and remove some of the uncertainty we spoke of earlier about the funding of the research.

Mr. **LUJAN**. So that might not necessarily be a proper formula for other disciplines. You cannot do biotechnology based on population or things like that, so it might not be——

Ms. **FRAZIER**. It is a different characteristic, a different type of research.

Mr. **FUQUA**. If the gentleman would yield.

As a matter of fact, the USDA is moving somewhat in the other direction of more competitive grants rather than the formula grants, which go back to, I guess, the Hatch Act and the Morrill Act and some of those, over 100 years old.

Ms. **FRAZIER**. Yes.

Mr. **LUJAN**. Yes. I was referring only to the facilities types of grants, not the overall thing; that that formula, somehow, gives more funding to infrastructure.

Did I gather that—did I understand that correctly?

Ms. **FRAZIER**. Because it establishes the centers and the work that is done. In the thicker of our two reports, that formula grant is described as little bit on page 131 and those pages talk about that for supporting the equipment and facilities work there. So if you wish additional information, it is there on that page.

Mr. **LUJAN**. Yes. I was not thinking of formula-type awards all the way across.

Ms. **FRAZIER**. Right. I understand that.

Mr. **LUJAN**. I perhaps misunderstood and thought the formula that they used was a certain percentage reserved for infrastructure, much in the same way at the chairman's legislation saying, you know, 15 percent—if that is the correct percentage—of all grants will go for infrastructure and I thought maybe you had run across one that——

Ms. **FRAZIER**. Oh, no, it is a different kind of—the awards are different.

Mr. **LUJAN**. I see. Thank you.

Thank you very much, Mr. Chairman.

Mr. **FUQUA**. Mr. Packard.

Mr. **PACKARD**. Thank you, Mr. Chairman.

Let me follow up briefly with the early questions of Mr. Lujan, in terms of institutions concentrating on obtaining grants. And he alluded to the idea that the enthusiasm of the institution may have a lot to do with the success of obtaining grants, and that that would carry over into the enthusiasm for research projects.

Is it possible that the opposite is true, also, in some instances where institutions may determine that they are not getting their fair share for grants and actually put together a grants team—a team of people that are really quite expert in obtaining—writing grant applications and obtaining grants? And, therefore, they increase the number of grants that they get?

I believe I saw—in your "Assessing Federal Mechanisms"—that the particular funding mechanism for university research played a lesser role in helping universities improve program quality than their ability to obtain grants. And I am wondering how much of that are we seeing in your study, where grants are often given because they are very good at getting grants, but do not particularly show any great expertise in the purpose for which the grant is being requested?

Ms. **Frazier**. I am sorry that we really cannot say that we addressed that particular point in terms of identifying whether the grants were sought for themselves rather than for justifiable research. What we did find was that there was a pattern of increasing the quality of the universities where we did our research and that was of a piece.

The way that we selected these five universities to look at in some detail was by referencing published documents which cite the reputation, more or less rank universities that show improvement. So we were looking at reported improvement over a number of years in the caliber of the particular departments in these universities, and I suppose that there is the possibility that, by publicizing themselves, they may have improved their ranking.

But, given the different factors that we examined, it looked as if the various steps they had taken to improve the quality and, perhaps, the number of faculty associated with the particular department, the caliber and number of graduate and postgraduate students associated with the department and so on, indicated that there was, indeed, an improvement in the quality of research that was going on.

Mr. **Packard**. So your study did indicate—particularly in that area—did indicate that there was a correlation between the ranking of the quality and the amount or the number of grants that were issued to that particular institution?

Ms. **Frazier**. Well, again, we did not actually assess the quality of the university's program, but we did find that there had been an increase in the amount of funding given to the university, as well as there had been an increase in the reputation of the university.

Again, we did not try to identify whether they were justified, if you will.

Mr. **Packard**. In your report, you indicate that, in conducting your study, you collected some information on—I think it was 7 nonprofit U.S. institutions, foundations, and associations that were in the business of granting funds for research. How did their procedures of making grants differ or parallel with the Federal Government's procedures in giving grants?

Ms. **Frazier**. I will refer this to Dr. Nadel.

Dr. **Nadel**. We decided to look at voluntary associations precisely for that reason, Mr. Packard, to see if there were any sort of magic bullets out there that were doing things in ways that were markedly different than Federal agencies—and perhaps markedly more successful.

Looking at the largest donors to university research, we found that they did things pretty much the same as the Federal agencies.

That is, they relied primarily on individual project support. Most of them used peer review processes and the award duration was in effect roughly the same.

That is not to say that there are not some foundations out there that we did not look at which use completely different and innovative techniques such as, perhaps, the MacArthur Foundation. But we tried to focus on the major donors.

Mr. **Packard**. In regard to that point, did your study indicate any glaring or obvious areas where we need to change the Federal granting or funding mechanisms? Any suggested areas that we ought to change?

Ms. **Frazier**. Well, one of the reasons that we focused in the second study on the use of center grants as opposed to individual project grants was to try to identify what—from the scientists' perspective—the differences were in some instances from these different kinds of mechanisms.

The area of great concern, of course, is the infrastructure—is it being adequately supported? And we found that, because individual project grant support actually, in many instances, includes some support for the infrastructure, it is not as clear as we might like to be able to tell you that the infrastructure needs a considerable amount of additional support in a direct fashion.

But there are some advantages that scientists reported from the center type grant, including stability of research, availability of seed money. Some of them reported that they felt more comfortable trying innovative or high-risk approaches. There was more multi-disciplinary work, or work that bridged two different areas of science, fields of science, so there are some advantages to some of the kinds of support approaches, funding mechanisms which are not just focused on individual project grants.

I think that that is one of the messages of our report that, perhaps, additional consideration of those mechanisms might be worth considering.

Mr. **Packard**. In your statement, you also indicated that, of the five universities that you used as resource study material, all of them leveraged funds that they had received. Have you found that the ability to leverage is a factor in the issuing of grants?

Kind of following the cost-sharing concepts that now seem to prevail here in Congress, are grants—the issuing of grants or the awarding of grants—influenced by the ability of institutions to leverage?

Mr. **Nadel**. On that issue, it should be noted that part of the strategy of a lot of the departments, when they made the commitment to increase their quality, was recruitment of new faculty. Often these new faculty had—in fact, almost always in the case of experienced faculty—they had a track record in obtaining Federal funding.

We do not want to dwell too much on the grantsmanship aspect of it. They were recruiting people who had national reputations. Part of the national reputation rested in doing research which would have been impossible to do without funding, so the two are very closely intertwined.

The leveraging aspect comes from getting initial seed money—sometimes from the university's own resources, sometimes from

Federal money—and using that seed money to recruit new faculty, some of whom brought money with them on existing programs, some of whom just had the experience to bring new money.

So that that was the kind of leveraging we are talking about.

Mr. PACKARD. One last question, if I may, Mr. Chairman.

Grants here from Federal resources are often influenced by political pressure, Members of Congress calling an agency and seeking a grant for an institution or someone within our own district. Is that ever done anywhere else? [Laughter.]

Did your study get involved in trying to evaluate what kind of influence this is having on the mechanisms?

Ms. FRAZIER. No, sir, at this time we were not looking at the actual awarding process for the grants. We were looking at it from the perspective of, within the universities of when they received the grants, what the characteristics were of those grants.

Mr. PACKARD. I would suspect you would want to avoid that, but maybe, still, it is worthy of—it is an interesting way to see if there is a correlation between the kinds of political pressures that are put on in relation to the actual awarding of grants or funding.

Ms. FRAZIER. Well, I do think it is fair to say that the university community is alert to the fact that, in some instances, funding is being awarded for research work by the Congress, rather than through the more normal peer review and competitive processes that have so often or primarily held sway in the past. And so there is some concern about the way that funds are actually received by universities—specifically in the area that you are mentioning.

Mr. PACKARD. If, in fact, that is a portion of the study, it would be interesting, not simply to know if that happens and to what extent. But how could it be made more of a level playing field for institutions to receive grants?

Ms. FRAZIER. Right.

Mr. PACKARD. On the basis of merit rather than on the basis of political pressure.

Thank you, Mr. Chairman.

Mr. FUQUA. Mr. Lewis.

Mr. LEWIS. Mr. Chairman, I just have one question.

On travel grants, did your study in any way show that they were abused? And what six types of funding mechanisms were they included in?

Ms. FRAZIER. No, sir, we did not look at travel grants specifically to identify whether or not there was a problem with those. We were looking at the grants in terms of funding projects as a whole, rather than looking at the funding internally and how it was handled—you know, within the individual grants.

Let me see if the others have any comments.

No. We did not look at that specifically.

Mr. LEWIS. Thank you, Mr. Chairman.

Mr. FUQUA. Your data confirms the concern, I think, that has been expressed in our task force agenda that there has been a gradual concentration in the use of project grants and a demphasis on the other funding mechanisms. You talk about 18 project grants, I think, mechanisms that were found in your study. And 16 of those are still in use. And, of the 16 institutional funding mechanisms found, 7 have been discontinued and only 9 are still in use.

Now, do you have any idea what factors led to those changes? Or what is the cause of that?

Ms. **Frazier**. We have, indeed, found that there has been a marked decrease in the use of many of the funding mechanisms from the 1960's and the 1970's—early 1970's—which were used to build up the facilities, provide specific training for universities to work on the building of equipment, the purchasing of equipment and so on.

Mr. **Fuqua**. Yes.

Ms. **Frazier**. But from the perspective of the agencies that we went to, it looks like a more gradual trend that we have seen, perhaps related to the peer review and the competitive process for actually awarding the grants. We have not, to my knowledge, found a specific reason that has shown or indicated a reason for the decline in the use of those grants.

Mr. **Perhonis**. Mr. Chairman, one observation: in putting together the trends in funding and noticing the rapid rise and decline in the 1960's of the institutional type programs that were used, both to maintain and develop—particularly to develop capacity—the prevalent use of project grants currently, I think, is related to the issue of accountability and the direct correlation between individual project grants and the particular purpose of the research, the particular program in the agency and the need to justify the funding of university research by particular agency mission needs—not only in the mission agencies, but the trend even went that direction in the agencies that did not have, like DOD, a very strict mission. So that, once the capacity was built for doing the kinds of things the agencies needed, and also to try to, in general, increase capacity, the emphasis, then, was on getting a particular project through the individual project support mechanisms. That has been our general observation on why project grants continue to be dominant and why institutional funding has been falling off.

Mr. **Fuqua**. Well, to take that a little further, the administrative burden associated with the project grant, including the, you know, writing of the proposal and then the peer review system that you go through with, and then the followup and so forth that we talked about earlier—and I think you indicated in the course of your study that the administrative burden varied from field to field of science and agency requirement, more than by the funding mechanism. Now, can you kind of give me a little better detail of what your conclusions are about how that has happened? And is there too much of an administrative burden?

Ms. **Frazier**. Is there too much of an administrative burden?

Mr. **Fuqua**. Yes.

Ms. **Frazier**. Well, I imagine that it depends from where you sit——

Mr. **Fuqua**. Right.

Ms. **Frazier** [continuing]. That a researcher might feel that there is, but an agency which would have a——

Mr. **Fuqua**. We are dealing with public funds and have to be accountable.

Ms. **Frazier**. Indeed. Indeed. And the importance of assuring that awards are made on the basis of merit or competitively to the highest quality and most important research and also that there is appropriate monitoring.

Mr. **Fuqua**. Yes.

Ms. **Frazier**. So we did not look to—try to determine whether there was too much in that sense. But, in regard——

Mr. **Fuqua**. Well, the concern is—and not to leave the thrust of the question—the concern is, are we driving researchers to other things because of, maybe, an excessive administrative burden, rather than trying to have an actual accounting of public funds, which I do not think anyone can expect any less of that, if you are dealing in public funds.

Certainly, if Congress has to extract the funds from the people to pay for the research, certainly the people are entitled to know what they are being spent for. And they look to Congress to make sure that we are making a proper accounting of that. But are we requiring too much administrative work?

But the other thing I am probably more interested in—and I realize that question will probably go on in debate for years to come. It has, as long as I can remember and we still have not solved it.

And then you have GAO come along and really shake them up, or other auditors show their presence.

But I am really concerned about some examples, maybe, of where the—in the fields of science, maybe in chemistry it is treated differently than engineering, or some other field. Do you have any information on that?

Ms. **Frazier**. We did look at five particular fields of science in this regard and, just in case you are interested in looking at it, this information is on page 33 of the thinner of the reports. In that one, on that page, you will see that we gathered some information that, in the chart that is there, that shows the number of days and weeks that are spent on administrative burden—and you can see the variations there.

Table 3.8: Average Time Spent by Scientists in Award-Related Activities

	Writing applications weeks/year	Proposal review days/year	Status reports days/year	Technical monitoring days/year	Noncompetitive renewal days/year
FIELD OF SCIENCE					
Plant science	5.6 n=10	18.5 n=11	6.3 n=11	3.6 n=10	3.7 n=9
Cell biology	4.7 n=12	15.5 n=10	5.4 n=14	3.1 n=14	1.1 n=14
Mathematics	2.0 n=20	5.9 n=20	2.6 n=18	.8 n=16	1.9 n=14
Space science	3.5 n=11	7.7 n=12	4.1 n=11	1.2 n=11	3.5 n=11
Artificial intelligence	3.9 n=10	9.7 n=10	6.6 n=9	6.4 n=9	1.9 n=9
All scientists	3.6 n=63	10.6 n=63	4.7 n=63	2.7 n=60	2.3 n=57

Now, again, our sample is not a very large one. We had talked to 70 researchers over all, across these five fields of science, from whom we gathered this information and you can see that there is some variation. For example, if you look in the second column, which talks about proposal review days per year, you will see that the plant science field found that they had approximately 18.5 review days for proposals, whereas that ranged down into the mathematics area of only 5.9 days per year. Technical monitoring days varied so that you found, several columns over, that artificial intelligence, which is a field that seems to be most frequently funded by the Department of Defense, is around 6.4 days per year spent on those kind of activities. And it varied again down into the mathematics area was a very small area, so, a small amount of time.

You can see that we did get a little bit of information about the variations on where the administrative burden falls and the one—the very first one—writing applications, which is weeks per year, indicates where, I guess, the bulk of that administrative burden falls. That shows that there is a variation from approximately 2 weeks per year for mathematics area to 5.6 weeks per year.

Dr. Nadel. In talking to the scientists, Mr. Chairman, many of them were really of two minds about a lot of the elements of administrative burden. While no one likes to spend a lot of time writing applications, a lot of people we talked to said that that did help sharpen their focus and it was a necessary exercise, so, you know, a lot of that time should not be considered dead time or unnecessary time. Similarly, the amount of time scientists spend in peer reviewing other proposals for NSF or NIH, they realize as one of their civic responsibilities in being in the community of science.

So a lot of this, they felt, was time taken away from their research. But a lot of it they also felt—at least the people we talked to—that it was, you know, part of the necessary price that they pay for being part of the research community.

Ms. **Frazier**. Thank you very much for the report, which is very good. You have a great accumulation of data that will be very helpful to us and I think it is in a very understandable format.

Thank you. Thank you very much for joining us.

Ms. **Frazier**. Thank you, sir.

[Whereupon, at 9:25 a.m., the task force recessed, to reconvene at 8:30 a.m., on Thursday, March 13, 1986.]

[Questions and answers for the record follow:]

RESPONSES TO QUESTIONS FOR THE RECORD
Hearing on Funding Mechanisms
March 12, 1986

Sarah P. Frazier
U.S. General Accounting Office

1. In your discussions with the six agencies from which you gathered data, do you find that they themselves have studied or otherwise reviewed the changing mix of funding mechanisms now in use to fund research? Are there any indications that any of the agencies are seeking to change the mix of funding mechanisms now in use?

Answer: During the course of our data collection at the six federal agencies, we became aware of at least four agency efforts relating to the evaluation of funding mechanisms. The Energy Research Advisory Board issued a report to the Department of Energy in August and October of 1983 focusing on the Department's policies toward and working relationships with the nation's universities. Among the issues discussed was the need for DOE to support equipment needs at universities as well as provide training opportunities through the DOE national laboratories. Recommendations in this study focused on the role of the universities in the DOE research planning process. (An Assessment of the Relationship Between the Department of Energy and Universities and Colleges. A Report of the Energy Research Advisory Board to the United States Department of Energy. DOE/S-0025, Vols. I & II, August, October 1983.)

DOD issued a report to the Committees on Armed Services in March 1985 addressing its role in supporting university research. Among other things, DOD addressed university equipment needs and manpower development by citing specific mechanisms addressing these concerns and estimating to what extent these areas are provided for through the traditional project grant or contract mechanisms. DOD also described its new program for FY 1986, The "University Research Initiative" which addresses on a broad front DOD support for graduate fellowships, young investigators, and purchase of research instrumentation. (The Technology Base and Support of University Research. A Department of Defense Report for the Committees on Armed Services, United States Congress, March 1, 1985.)

The NASA-University Relations Study Group reported on funding mechanisms in its initial July 1983 report entitled "The Universities and NASA Space Sciences." Both university equipment grants and graduate student fellowships are cited as having a positive impact on university research groups in the short run. (The Universities and NASA Space Sciences. Initial Report of the NASA/University Relations Study Group. July 1983.)

Finally, NIH has continually studied the length of research grants through various institute studies. NIH has also recently studied mechanisms specifically aimed at providing support to M.D.'s doing research, and has implemented several new mechanisms aimed at support for small colleges as well as new investigators. (Personnel Needs and Training for Biomedical and Behavioral Research, A report by the Institute of Medicine, National Academy of Sciences, 1983.)

2. You note that the GAO analysis of the shifting balance between the various types of funding mechanisms is based on an analysis of trends in various types of funding rather than of data about the different types of grants themselves.

Since many of the agencies use extensive computerized data banks with information about all individual grants, why not use this directly relevant data instead of the indirect data concerning funding, with its limitations, such as the inability to distinguish between project support, program support and center support?

Answer: With the exception of NIH, none of the agency data banks have information specifically on the funding mechanisms we developed for cross-agency comparisons in our report (GAO/RCED-86-53). NIH has trend data categorized by specific funding mechanisms, including individual project, program, and center support. However, NIH officials told us that the data for some of these mechanisms were not reliable beyond certain years (10 years in some cases) because of shifts in mechanism definitions. Agency data banks are useful for agency specific studies, but are not useful for the cross-agency comparisons we were trying to make in our report.

3. A significant amount of support for universities, including support of infrastructure needs such as research libraries and graduate students, has in past years been provided under the Higher Education Act. Do you have any indications, from your contacts with the research agencies, whether your conclusions would be changed if those programs were included in your survey?

Answer: The data we have on agency funding mechanisms is a result of asking six federal agencies to submit to us information under the funding mechanism categories we developed. In both gathering and presenting data for our report, GAO did not characterize federal agency research programs by legislative source. Therefore we cannot respond to this question without further research. Our data on trends in federal support to universities from 1963 to 1982 was taken from an annual NSF publication, Federal Support to Universities, Colleges, and Nonprofit Institutions, FY 1982, and includes federal funds for support of university research as well as facilities, and training support. These funds are from 15 federal agencies, including the Office of Education.

4. You note in your report that since 1963, grants for the direct support of various infrastructure needs at the universities have declined from 38% to 13% of all grants. Indirect funding for infrastructure is provided through the overhead costs. How has that mechanism of infrastructure funding varied over this same time period?

Answer: Unfortunately there are no nationwide data on the portion of university indirect costs related to infrastructure prior to the 1982-1984 data which Henry Kirshenmann, Jr. of the Department of Health and Human Services presented to the Task Force on May 21, 1985. Mr. Kirschenmann's data showed building and equipment indirect costs accounting for 9 to 10 percent of total indirect costs, and operations and maintenance claiming 27 to 28 percent. Using these figures, Mr. Kirschenmann estimated that building and equipment indirect cost reimbursements were $123 million in 1982, $130 million in 1983, and $163 million in 1984. Reimbursements for operations and maintenance for the same years were $351 million, $412 million and $482 million respectively. Additionally, we understand that indirect costs associated with operations and maintenance rose rapidly during the mid-to-late-seventies due to the run-up in energy costs. To the best of our knowledge, although data aren't available, there have been no significant changes in how indirect costs related to infrastructure (i.e. depreciation/use allowance for buildings and equipment and operations and maintenance) have been calculated since the overall cap on university indirect cost rates was lifted in 1966.

5. In your analysis of the different types of funding mechanisms used to support university research, do you find any connection between certain types of grants and particular agencies? To be more specific, do some agencies tend to use some kinds of funding mechanisms more than others?

Answer: Agencies do differ in their use of funding mechanisms. The mainstay of USDA's support for university research takes place through formula funding to the nation's agricultural experiment stations. Only recently has USDA complemented this form of institutional funding through individual competitive grants which are peer-reviewed. Conversely, the predominant form for support for university research in DOD is the individual research contract. Only recently (FY86) has DOD developed a form of institutional funding to complement this form of support (University Research Initiative). NSF and NIH were the only two agencies to report use of the post-doctoral fellowship mechanism. NIH uses the post-doctoral fellowship the most among the six agencies and is the only agency to use the training grant. Concerning use of program or center support, USDA reported no funding, while the other five agencies did report funding, with NIH making most use of these mechanisms.

6. A question about the method of classifying the various funding mechanisms, specifically about the levels specified in the GAO classification scheme: Under NSF you list "NSF Individual Research Project (Grant)", but under DOE you list a specific type of individual research project grant, namely

the DOE "Distinguished Scientist Grant." We know that NSF also had a type of grant called "Senior Investigator Grant," but this is not listed as a separate type of funding mechanism, while a comparable type for DOE is so listed. Is this consistent?

Answer: We asked each of the six agencies to identify the funding mechanisms they use within the six categories of funding mechanisms which we used for our study. The specific titles for each agency funding mechanisms reflects how that mechanism is identified at the agency. Regarding NSF's "Senior Investigator Grant," we spoke with the Director of NSF's Division of Research Career Development. He told us that NSF had not had a program with that particular title. However, NSF has had two programs of the "senior-investigator" type, a senior post-doctoral fellowship program and a senior foreign scientist fellowship program. These programs are described on pages 127 and 128 of the report on Federal Funding Mechanisms.

7. The duration of awards is an important factor in providing continuity to the research community. Do you have any data to reflect trends in award duration over the past five to ten years?

Answer: NIH was the only agency that could provide us systematic trend data for project award periods. During the past ten years, the average duration of NIH individual research projects has remained around 3 years, with little fluctuation from year to year; for program project support, average project periods have increased from 3.7 years in 1974 to 4.3 years in 1984; for center support, average project periods have increased from 3.2 years in 1974 to 4.0 years in 1984.

NIH defines project period as the number of years, contingent upon yearly appropriations, an awardee can expect to receive funds without competing for a renewal. These figures for duration, therefore, do not indicate the length of time a project is actually funded. After a project period is completed, an awardee may compete for additional funds to continue research. While NIH has an average duration of 3 years on an individual project grant, the average length of time that individual projects are actually funded is 5.5 years. This indicates that about half of the initial awardees are granted renewal awards.

8. For many years, the NSF has provided support for a group of 15 materials research centers at various universities. NSF has also supported a group of astronomy research facilities. In your report, you distinguish between NSF "Research Programs" with an average award size of $1 million and NSF "Research Centers" with an average award size of $1.3 million. Can the GAO provide for the record a listing of which centers and programs fall into each category?

Answer: In reporting to us, NSF listed its materials research laboratories under "research programs." Under center support, NSF listed the following university centers:

--Micro-fabrication Facility (Cornell University)

--Synchrotron Research Center (University of Wisconsin)

--Cornell High Energy Synchrotron

--Math Research Centers (University of California at Berkeley) (University of Minnesota)

--National Magnet Laboratory (MIT)

--Cornell High Energy Physics Accelerator

--Industry-University Cooperative Research Centers. (35 universities)

There was also support in the "center support" category that NSF did not specifically identify. In addition NSF did not include astronomy facilities under the center category because they are federally funded research and development centers (FFRDC's), which were beyond the scope of our study.

9. One of the conclusions in your second report, where you assess the effectiveness of the various funding mechanisms, is that innovative, high-risk or interdisciplinary research is more likely to be conducted under center funding than under project funding. Since innovative research is highly desirable, are there any reasons we should not draw the conclusion that more research sould be funded through center grants as opposed to project grants?

Answer: Because of the limited nature of this data, we cannot conclude from our results that more research should be funded through center grants as opposed to project grants.

The center researchers we interviewed reported they were more likely to propose innovative, high-risk, or interdisciplinary research, but both scientists in centers and those with individual project grants reported that they had equal success in receiving funding for innovative research projects. The conclusion that more research should be funded through center grants as opposed to project grants cannot necessarily be drawn from our report. However, scientists in centers believed they had more freedom to propose innovative research projects.

More center scientists than scientists with individual project awards reported performing interdisciplinary research. However, the field of science also influenced whether center scientists or scientists with individual project awards reported they did interdisciplinary research. For example, all plant scientists, whether they had center awards or individual project awards, described their research as interdisciplinary. Moreover, our report was based on the perceptions of 70 researchers at 10 universities in response to our questionnaire, and these perceptions may not be generalizable to the scientific community as a whole.

RESEARCH FUNDING MECHANISMS

THURSDAY, MARCH 13, 1986

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to notice, at 8:30 a.m., in room 2318, Rayburn House Office Building, Hon. Richard H. Stallings (acting chairman of the task force) presiding.

Mr. Stallings. Ladies and gentlemen, we welcome you to our morning's testimony before the Science Policy Task Force.

We are very fortunate to have Dr. Pings with us today.

This morning is the second of a series of four hearings on research funding mechanisms.

Yesterday, the GAO presented the results of their study of the funding mechanisms used by the six major Federal agencies who fund scientific research. The results of the GAO study have confirmed that there has been an increasing reliance on the use of individual project grants over the past 30 years.

At the same time, direct support of the research infrastructure has declined, both in percentage of award funds and in actual dollars.The ways in which we provide funds for the conduct of scientific research may have profound effects on the type of research performed.

In order to determine the relative strength and weaknesses of the current mechanisms used to award research funds and the impact of the system on the research effort, individuals from various sectors of the research community have been invited to testify before the task force during the remaining 3 days of hearings on this topic.

Today we are very fortunate and we welcome Dr. Cornelius J. Pings, provost and senior vice president for research at the University of Southern California.

Dr. Pings will speak to us from the perspective of a research administrator.

Good morning, Dr. Pings, and we would like you to proceed.

STATEMENT OF DR. CORNELIUS J. PINGS, SENIOR VICE PRESIDENT FOR ACADEMIC AFFAIRS AND PROVOST, UNIVERSITY OF SOUTHERN CALIFORNIA, LOS ANGELES, CA, AND FORMER DIRECTOR, NATIONAL COMMISSION ON RESEARCH

Dr. Pings. Good morning, Mr. Chairman, and thank you for your invitation to appear before your Task Force on Science Policy.

Mr. Chairman, I request permission to submit for the task force records the written reports which I submitted to staff earlier this week but which I will not endeavor to read in entirety today.

I had an advance copy of the report from the General Accounting Office on funding mechanisms made available to me and I will try to use, where I can, the notations and descriptions consistent with that report.

I want to make it clear that the views expressed here today are mine, although I have reason to believe that much of what I suggest here is broadly shared with many of my colleagues in the university science community. Nevertheless, all views are influenced by personal experience. I should let you know that my own Ph.D. work at Caltech was done in a major research center which existed for more than 40 years and was a center that had prodigious impact on the understanding of the behavior of fluids in petroleum reservoirs. On the other hand, my own career as a principal investigator for 4 years at Stanford and for more than 20 years as a faculty member at Caltech involved support from a variety of project contracts and grants.

I have seen many of the outcomes, problems, and responses to the support of research from a sequence of administrative positions: chairman of the chemical engineering program at Caltech, vice provost and graduate dean at the same institution—and in my current role as senior vice president for academic affairs and provost at the University of Southern California. This has included direct negotiations and discussions with a wide collection of Federal agencies and the opportunity to observe support through the collection of formats identified in the GAO report. I have been in the position to observe particularly the impact of these various support mechanisms on the development of careers of graduate students, young faculty and the more established investigators.

I mention also that I was a member and director of the National Commission on Research, which carried out a number of studies in the time period between 1978 and 1980. Among the areas of inquiry and reports prepared by that Commission was one on funding mechanisms. Although that was published in May 1980, some of the data presented are somewhat out of date. The fundamental concepts still appear valid and seem to be generally supported of the analysis of the GAO report. Mr. Chairman, I would like to offer for your records that report on funding mechanisms prepared by the National Commission on Research and copies have been made available.

Now, with those disclaimers, I will presume to give you some analysis of funding mechanisms and, finally, some recommendations.

I am going to review and comment on the several funding mechanisms suggested in the GAO report earlier this week. Also, I am going to remind us of the missions and objectives of our research universities, including desirable attributes of a healthy research program. Then I will make a best effort at putting these together, specifically attempting to assess each of the identified funding mechanisms in terms of effectiveness and relevance to the educational research objectives of the university.

Let us, then, to the mission and objectives of universities.

There are some 3,300 colleges and universities in this country, as you well know. The predominant number do not have Ph.D. programs or significant presence of research activity. A small subset—say of the order of 100—carry on significant research programs and that group accounts for approximately 60 percent of all fundamental research carried out in the Nation and they approach 70 percent of the basic research funded by the Federal Government. In those institutions, we can truly say that education is going on in the context of creation, storage, and transmission of new knowledge.

Some of that research is engineering or applied research, but relatively little of it is development, and properly so. First, all of those institutions are turning out a joint product, namely research results, and trained and educated people. So we get the research accomplished while we are training the next generation of faculty members for universities and the research staff for industry, national labs, and the broad, technological enterprise of the Nation.

What attributes might be indicators of whether we are succeeding in our basic mission?

Here are some suggestions, not exhaustive, but intended to be responsive to the subject that we are dwelling on here this morning and, particularly, funding mechanisms.

I have listed these in six categories and subcategories. Very quickly and sketchily, one would be effective support of Ph.D. programs in science and in engineering; support of young investigators; assurance of lifetime career possibilities for established investigators; assurance of quality research—basic research in science, some applied research in engineering.

We want a system that is flexible and responsive. There should be prompt response to new research opportunities and, I believe, equally important, assurance that we will discontinue or shift away from programs and projects that have by now become outmoded or may just be simply still of quality but lower priority.

We do have to have capacity in a research enterprise to respond to national needs for the development of new technologies. They should provide a way for us to collect necessary personnel and infrastructure. We would look to enhanced transfer of new discoveries to the Nation's technology base, and I think we could definitely stand some enhanced interaction with industry and, occasionally, with the national laboratories of the Federal Government.

There should be a long-term stability and commitment. There should be stability for graduate students and faculty groups. I think there should be a mutual responsibility for funding agencies and of the universities to provide better than we have for the long-term maintainance of infrastructure.

Now let me turn to the funding mechanisms, and again, I will use the nomenclature and categorization in the GAO report as a point of departure.

There were six major categories, as you will recall, in the testimony made available to you earlier this week. Three in the direct support of research: individual project support and program support and center support. Three categories tending to the research infrastructures: special training needs, major equipment facility grants and institutional support. I believe these really are pertinent categories. Indeed, the GAO report certainly presents statistics to show that this accounts for almost all university research funded by the Federal Government.

I would like to caution, however, that we should not assume that these are mutually exclusive and represent some sort of sharply defined bins into which we can classify all research activities on our campuses. To the contrary, there really is a continuous spectrum and a high level of interaction among these six areas.

For example, a given science department on a typical campus at first look may seem to have only principal investigators sponsored by the individual project grants. Yet you could very well find several such faculty members with common overlapping research interests voluntarily aggregating their work into a program for short such joint purposes as graduate student recruiting, maintainance of a spectrometer or another piece of joint equipment, joint work in seminars and colloquia, and so forth.

Of course, there is the distinction between a program and a center also, and it is not that sharply drawn. I think we have all noted that a program or a collection of faculty with related interests often evolve into a center because of the availability of funds from a State or Federal agency.

It is also clear that the problems of maintenance of the infrastructure are not addressed solely by grants in the three areas listed in the GAO report. Through the years, many more students have been supported, for example, by research assistantships provided in the budgets of individual project grants than by formal training grants. Also, individual project grants often provide for equipment purchases—although, admittedly, only for large pieces of equipment and hardly ever for construction or substantial renovation of facilities.

There is very little institutional support coming to our universities in association with the collection of individual project grants. In fact, the cognizant A-21 circular of the Office of Management and Budget on cost accounting principles for colleges and universities has systematically denied to that community anything equivalent to the institutional research and development funds routinely made available to the industrial contractors doing Federal research. On the other hand, both program and center support very likely can tacitly provide for some institutional support, particularly for summer salaries and other initiation expenses for young faculty.

Now, given all the above, I am going to presume to add another category, if I might, of funding mechanism to the list that was in the GAO report—namely, a hybrid. So, in my listing, I have a category seven which is a combination of individual project support combined with appropriate grants for training, equipment facilities and institutional support.

Now, there is nothing new or novel about this latter suggestion. Of course, it represents, to a significant extent how we have done business for the last four decades, not adequately, I would suggest, but nevertheless, the principle has been there.

We now have in front of us seven categories of funding mechanisms generally paralleling the categorization of the GAO report and I will try to comment on each of them against the attributes that I identified earlier as desirable.

Now, the individual project/principal investigator support is the dominant mode, still, of support by the Federal agencies of engineering and science research by faculty on our campuses, as you noted in your introduction, Mr. Chairman. Through a number of Government agencies, the typical award to faculty member is based on evaluation of unsolicited proposals. These proposals are professionally reviewed, sometimes by elaborate peer review processes, sometimes largely by professional staffs. The area of research and the specific line of inquiry is proposed by the individual faculty members, although judgment exercised in the review process does allow the agency to develop a thrust of research in certain areas.

This type of mechanism is particularly flexible and adaptive to starting research in new areas. Any investigator is free to put in a proposal for a new topic or a different type of experiment. Perhaps as a corollary to that rapid adaptation, this mechanism is very effective in the establishment of young faculty as independent principal investigators.

The principal investigator project support mechanism provides maximum flexibility for adaptation of budgets to expenses peculiar to the proposed investigation. Such support does rarely pay for the cost of elaborate instrumentation or facilities, but can be reasonably responsible for modest basic instrumentation—a good means to support graduate students.

This mechanism of project grants and support can provide for long-term stability of support. Sure, grants are typically for a definite period of time—typically 1 to 3 years, subject to renewal or extension based on a fresh proposal. But I know of many principal investigators who have kept research programs going without interruption for several decades, with support from the same agency or a mixture of agencies based on periodic resubmission of proposals.

But support can equally easily be discontinued—as many of us have found out—if new proposals are not submitted or results of the research reflect lack of freshness and imagination, particularly when placed in juxtaposition to competing proposals for new and innovative work. The system is, indeed, one of acute competition.

Finally, I believe the individual project investigator grant mechanism is a rather weak tool if an agency is attempting to foster cooperative or concentrated research in a given area.

Let me turn to project support. In this context we are using the descriptor of "project support" to identify the collective activities of several faculty members with related research interests.

Effort invested in proposal writing and subsequent technical reporting might be less under this mechanism than would be required for a collection of principal investigators involved in the same activity, since this is presumably a less formal structure than the center project—which I will discuss in a moment—but one presumes there is a minimum of internal administrative structure.

From the viewpoint of the funding agency, the project may be a gentle tool in an effort to get research focused in a particular area. Some degree of concentration on a common theme could be encouraged but stopping short of the sharper focus usually associated with the center.

Now, let me turn to the center which presumably goes significantly beyond the program support, both in internal administrative structure and also as a strategy of guiding most of the research within prescribed channels. Overall, this makes it possible to respond to some agreed-upon areas of concentration as worked out with the funding agency.

I believe, in the extreme, the center concept is antithetical to the principle that faculty members and senior graduate students should be free to pursue lines of inquiry suggested by the research itself. Therefore, in general, I think the center concept is particularly inappropriate in most instances for support of basis science research on our campuses.

On the other hand, our engineering research community can and should be putting some of its capacity into larger scale research endeavors. On selected topics, ranging from circuit design to dynamic response of large systems to safety strategies of chemical plants, research often benefits from parallel efforts from several groups on a given campus. It is an effective way, also, to bring industry and national laboratories into the program, making equipment available and training personnel. Therefore, when a funding agency senses a need for increased research activity in an applied area, there is a clear merit in establishing and maintaining an appropriate center on a university campus.

But I would advocate centers in moderation and only when funding agencies are confident that they have already paid attention to the research in the normal disciplinary areas. I personally believe that no center should ever have the right to make faculty appointments, admit graduate students, or award degrees. These should be the responsibility and prerogative of strong disciplinary departments.

I have mixed reactions about centers with respect to young faculty members starting their careers. The center may provide an extraordinary opportunity for the faculty member to have summer salary support, immediate access to support of graduate students, availability of equipment that otherwise would take years to assemble, and an immediate working relationship with senior colleagues.

In all of the above, there is also potentially a lethal trap. We expect our junior faculty members to present records of independent accomplishment at the time they are considered for tenure. Service as assistant director on a project will not usually be an adequate substitute for a record of scholarly publications.

There can be other problems—personnel problems with projects. Universities will tell you very firmly the projects should never be started unless there is a reasonably convincing commitment from the funding agency to provide stable funding over a number of years, including adequate notice if there is to be a turndown or discontinuance. The university, on the other hand, is in a weak position to provide assurance of ongoing participation by any given set of faculty individuals. It is the nature of our university setting that participation in such projects by faculty members is voluntary and faculty members may come and go. There is a rather cloudy issue of whether responsibility for the success of the project is really that of the university, the school of engineering, or the level of individual principal investigators who have aggregated to submit the proposal.

Let me turn quickly to several items in the infrastructure in the GAO categorization.

There have been several experiments with training grants, but the only program that has persisted for many years is that of NIH and it has been particularly effective. In my view, it would be a serious mistake to sprinkle training grants around on an independent basis without assurance that the recipient institutions already have in place substantial research capability.

On equipment and facility grants, I will be brief, but it profits in inverse proportion to the significance of this area of funding. None of the three mechanisms discussed previously for the direct support of research provide adequately for the purchase and maintenance of equipment, renovation and construction, new facilities and for systematic rehabilitation of facilities used for ongoing programs. One result is the investment made by the funding agency in direct support of research is often less than optimally used because we have some of the best minds in the form of graduate students and faculty carrying out research on antiquated equipment and computers.

All of our major universities invest a large amount of institutional funds in the initiation and support of research programs. I do believe that there could be a very high return on modest amounts of institutional money awarded from the Federal Government to the universities but, in turn, restricted to the support of the ongoing research program. The Biomedical Research Support Grant Program of NIH is an excellent example of this. Unfortunately, as you know, funding for that is being zeroed out this year.

We do need funds to start young investigators, do institutional recruitment of graduate students, provide for the maintenance of equipment and other shared endeavors. We are living off our capital and some future generation of public servants and university administrators and, above all, practicing scientists, will properly belabor us for it.

I come again to the hybrid support which I think is known, but could be honed and developed to a program of ongoing support through projects, principal investor grants, supplemented by institutional training and equipment grants.

Mr. Chairman, I have tried to collect my assessment above of the several funding mechanisms into the table, where I, essentially, rate the seven categories against the attributes that I identified earlier.

Assessment of Research Funding Mechanism

		Support Ph.D. Programs in Science	Support Ph.D./M.S. Programs in Engineering	Support Young Investigators	Career Development	Quality Research - Science	Quality Research - Engineering	Response to New Opportunities	Discontinuance of Low Priority Programs	National Needs	Personnel	Transfer of Technology	Interaction with Industry/Government Labs	Stability for Students/Faculty	Infrastructure
I	PI Grants	P+	P	P	P	P+	P	P+	P		N	N	W	P	W
II	Program	N	N	W	N	N	N	N	N		P	P	P–	N	N
III	Center	W	P–	W/D	W	W	N	W	W		P+	P+	P+	N	P–
IV	Training	P+	P	P	–	N	N	N	N		N	N	N	N	N
V	Equipment	P	P	N	N	P	P	N	N		P	P	P	N	W
VI	Institutional Support	P+	P	P+	P+	P+	P+	P++	N		N	N	N	P	P+
VII	Hybrid	P+	P+	P+	P+	P+	P+	P+	P		P	P	P	P+	P+

P	Positive
N	Neutral or Not Germane
W	Weak
D	Deleterious

Dr. PINGS. Perhaps a strange grading scale, but P is positive, ranging on down through D, which was deleterious.

What might we conclude? Certainly that Vannever Bush was perceptive and persuasive in his argument that the resources of the Nation should be brought to bear on establishment support of a national program of pure and applied sciences largely located within our universities. Congress has provided oversight, authorization and appropriations. The agencies have constructed an experiment with a variety of programs and the university community has responded, I believe, magnificently in creating a system of joint research and training that is the envy of the rest of the world. I am personally persuaded that two of the reasons for success have been diversity in competition among agencies of the Government to foster and support quality programs, and competition among the universities.

Certainly there are defects, shortcomings, problems, and opportunities to improve. The scientific community and the Nation recognize that this is why the House Task Force on Science Policy has undertaken its current review.

It seems indeed proper to pause and ask if the program's techniques, processes and levels of appropriations that have served us well for 40 years since World War II represent the best strategies to take us into the early years of the 21st century. Specifically with respect to funding mechanisms, I believe that, overall, our recent and current mechanisms and processes are sound and should not be the subject for radical change.

It would be my recommendation, as we move forward, that the dominant mode of support should continue to be the individual principal investigator grant contract awarded in open competition in response to proposals. Particularly in the area of basic sciences, this will assure generally the best quality of research, the quickest response to new opportunities for research, the best assurance of shifts away from low-priority areas, an absolutely first-class mechanism for rapid placement of young faculty in the system, and a very important form of stable support for graduate students.

That overall program has been weak in providing for current quality instrumentation, renewal of facilities and construction of new plants. There has also been a shortfall on increment of institutional support. That is why I have advocated the hybrid approach.

Upon reflection, I find myself rather indifferent to program support. The center concept is more structured than the program. Except for very rare circumstances or opportunities, it is my opinion that the center concept should not be avidly developed as a means of supporting basic science research on our campuses, nor should it become a substitute in the areas of engineering and more applied activity for support of the disciplinary programs. But there is a place for centers in limited and controlled amounts and there is mutual agreement between an agency and a campus that a group can advantageously be brought together to concentrate students and faculty efforts and equipment and so forth on a particular area of inquiry or the development of a new technology.

There is one ongoing problem with respect to centers, namely, stability and continuity of research. You would certainly find me, as a current campus administrative officer, arguing that any center we establish on our campus ought to be carrying from the funding agency assurance for reasonably long-term support, subject to appropriate review. On the other hand, personnel at the campus level come and go—but, most importantly, fields of interest wane and new opportunities present themselves. There is, therefore, real need for mechanisms that provide for extraordinary vigilance with respect to the current relevance and quality of research carried out under the center mechanism and we need the institutional courage to redirect or even stop when that operation has been passed by.

In closing, Mr. Chairman, I appreciate the privilege of appearing before you this morning and want to leave you with several summary thoughts.

The ability of the United States to compete economically and industrially in the international marketplace is an unequivocal national goal. Not only must we be a participant in that area, I suggest we must win. As in most competition, coming in second is really losing. If we are serious, and serious we must be, then let us behave consistently and assure that we attend to the fundamentals, the training of skilled personnel, and the flow of science and engineering research without which there will be no new technology. I urge the task force to endorse a continuation of the best science research and education establishment in the world, above all, please pay attention to the infrastructure. The best minds of our society deserve better than we have provided for them in the way of facilities, equipment, and general support.

Mr. Chairman, thank you very much.

[The prepared statement of Dr. Pings follows:]

EXECUTIVE SUMMARY

Cornelius J. Pings' Testimony
Task Force on Science Policy

1. Overall our funding mechanisms and processes are sound; no need for radical change.

2. The dominant mode of support should continue with individual principle investigator grants and contracts awarded in open competition in response to proposals.

    - Assures shifts away from low priority areas of research
    - Is a first-class mechanism for rapid placement of young faculty in the system
    - Provides for stable support for graduate students

3. The overall program has been weak in providing for current quality instrumentation, renewal of facilities, and construction of new plants.

4. There has been a shortfall in any increment of institutional support for reinvestment in the campus research enterprise (hybrid approach).

5. The supplemental program in training grants generally has contributed to enhanced quality of Ph.D.s but only if available on a long-term basis.

6. Indifferent to program support because of the dangers of entrapment for young faculty members.

7. The Center concept should be only for occasional opportunities in engineering research and should not be avidly developed as a means to support basic science research on campuses.

8. We must attend to the fundamentals so that the United States will continue to compete economically and industrially in the international market place.

    - Training of skilled personnel
    - Flow of science and engineering research
    - Attending to the infrastructure: facilities, equipment and general support.

Testimony Before the Task Force on Science Policy of the Committee on Science and Technology of the US House of Representatives

Session on Research Funding Mechanisms

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Mr. Chairman, members of the Committee, thank you for your invitation to appear before the Task Force on Science Policy. It is a privilege to share with you some of my views on today's topic of funding mechanisms for Federal financial support of scientific research performed principally at the universities and colleges of our nation.

Your time is limited, and I request permission to submit for the Task Force records the written report which I provided the staff earlier this week; I will not endeavor to read it in its entirety today.

Also, to save time, I wish to inform you that I have reviewed the objectives and activities of the Committee since its inception in late 1984, and am aware of the topics that have been considered and the witnesses that have appeared before the Committee. Specifically, an advance copy of the report from the Government Accounting Office on funding mechanisms was made available to me. In order to be as efficient as possible, I will use notations and descriptions consistent with that report and will minimize recapitulation. My testimony to you is opinions on the relative effectiveness, advantages, disadvantages, problems, and opportunities for improvement for the various funding mechanisms that are so well identified in that GAO document.

The views expressed here today are mine, although I have reason to believe that much of what is suggested here is broadly shared with many colleagues in the university/science community.

Nevertheless, my views are inevitably influenced by my personal experience. First of all, let me inform you that my own Ph.D. work at Caltech was done in a major research center, which existed for more than 40 years and had a prodigious impact on understanding of the behavior of fluids in petroleum reservoirs. My own career as a principal investigator for four years at Stanford and for more than 20 years as a faculty member at Caltech involved research support from a variety of project contracts and grants. My experimental and theoretical work on the fundamental properties of liquids was started with an initiation grant from the Research Corporation and then was generously supported through more than two decades by a variety of support mechanisms from the National Science Foundation, the Chemistry Directorate of the Air Force Office of Scientific Research, and from the Metallurgy Branch of the Office of Naval Research.

I have also seen many of the outcomes, problems and responses to the support of research from a sequence of administrative positions: chairman of the Chemical Engineering program at Caltech, Vice Provost and Graduate Dean at the same institution, and in my current role as Senior Vice President for Academic Affairs and Provost at the University of Southern California. This has included direct negotiations and discussions with a wide collection of Federal agencies and the opportunity to observe support through the collection of formats identified in the GAO report. I have been in a position to observe particularly the impact of these various support mechanisms on the development of careers of graduate students, young faculty, and more established investigators.

Finally, in these introductory remarks, let me mention that I was a member and the director of the National Commission on Research which carried out a number of studies in the time period between 1978 and 1980. That Commission reported to the House Committee on Science and Technology on the contents of one of its major reports, namely, "Accountability: Restoring the Quality of the Partnership." Among the other areas of inquiry and reports prepared by that Commission was one on "Funding Mechanisms." Although that was published in May 1980, and some of the data presented are somewhat out of date, the fundamental concepts still appear valid and seem to be generally supportive of the analysis of the GAO report. Mr. Chairman, with your permission, I would like to offer for your records that report on "Funding Mechanisms" prepared by the National Commission on Research.

That should be enough highlighting of personal experience to forewarn you of possible bias based on professional experience. With that disclaimer, I presume then to give you some analysis of funding mechanisms and finally some recommendations.

I am going to review and comment on the several funding mechanisms suggested in the GAO report. Also, I am going to remind us of the mission and objectives of our research universities, including desirable attributes of a healthy research program. Then I will make a best effort of putting these together, specifically attempting to assess each of the identified funding mechanisms in terms of effectiveness and relevance to the educational and research objectives of the university.

Let us turn then to the mission and objectives of universities. I have nothing to tell you that you do not know, but at the expense of seeming pedantic, it will be useful to have a checklist against which we can assess these funding mechanisms.

There are some 3,300 colleges and universities in this country. All of them are dedicated to education and training through a variety of degree, certificate, and continuing education programs at the undergraduate, graduate, and professional levels. Many of those institutions expect their faculty to be active scholars, but the dominant number do not have Ph.D. programs or significant presence of research activity. A small subset, say on the order of 100, carries on significant research programs. That group accounts for approximately 60% of all fundamental research carried out in the nation and approaches 70 percent of the basic research funded by the Federal Government. In those institutions we can truly say that education is going on in the context of creation, storage, and transmission of new knowledge.

Some of that research is engineering or applied research, but relatively little of it is development, and properly so. Of course, those institutions are turning out a joint product, namely research results and trained and educated people. Processes are highly intertwined. Ph.D. students and postdoctoral fellows are educated broadly and become trained in techniques. But in the process they are significant doers of research. So we get the research accomplished while we are training the next generation of faculty members for universities and the research staff for industry, national laboratories, and the broad technological enterprise of the nation. Somehow this all gets adequately administered and managed, and costs are met, at least out-of-pocket operating costs.

If we were attempting to assess the effectiveness of this university-joint educational and research enterprise, what attributes might be indicators of whether we were succeeding in our basic mission? Here are some suggestions, which are not exhaustive because we are dwelling on features that are particularly relevant to the funding mechanisms issue.

1. Effectiveness in education and training of research personnel
    - 1.A. Effective support of Ph.D. programs in science
    - 1.B. Effective support of both M.S. and Ph.D. programs in engineering
2. Career development of faculty
    - 2.A. Support of young investigators
    - 2.B. Assurance of attractive lifetime career possibilities
3. Assurance of a comprehensive program of quality research
    - 3.A. Almost exclusively basic research in science
    - 3.B. In engineering some component of applied research
4. A flexible and responsive system
    - 4.A. Prompt response to new research opportunities
    - 4.B. Assurance of discontinuance or shift away from programs and projects that have become outmoded or are simply of lower priority
5. Capacity to respond to national needs for development of new technologies
    - 5.A. Collection of necessary personnel and infrastructure
    - 5.B. Enhanced transfer of new discoveries to the nation's technology base

    5.C. Enhanced interaction with industry and with mission-oriented laboratories of the Federal Government

  6. Long-term mutual commitment

    6.A. Stability of graduate student and faculty groups

    6.B. Mutual responsibility for long-term maintenance of infrastructure

Let us turn now to the funding mechanisms that are prevalent and use the nomenclature and categorization in the GAO report as a point of departure.

Direct Support of Research:

I. Individual project support

II. Program support

III. Center support

Research Infrastructure:

IV. Special training needs

V. Major equipment and facilities

VI. Institutional support

These are the really pertinent categories, and the GAO report certainly presents statistics to show that this accounts for almost all of the university research funded by the Federal Government. One should be cautious, however, in assuming that these are mutually exclusive and represent sharply defined bins into which we can classify all research activities on our campuses. To the contrary, there really is a continuous spectrum and a high level of interaction among these six areas. For example, a given science department on one of our typical campuses may seem to have only principal investigators sponsored by the individual project grants. Yet one might very well find several such faculty members with common or overlapping research interests voluntarily aggregating their work into a program for such joint efforts as graduate student recruiting, maintenance of a spectrometer, joint working seminars and colloquia, etc. Thus it would not be unusual in counseling undergraduate students seeking a location for their Ph.D. work to talk about the "program" in synthetic organic chemistry at Stanford, or the "program" in chemical physics at Caltech, even though the faculty involved would not necessarily have represented themselves to any funding agency as carrying out a formal program in that area.

Of course, the distinction between a program and a center is also not that sharply drawn, and often a program or a collection of faculty with related interests evolves into a center because of availability of funds from a Federal agency.

It is also clear that problems of maintenance of the infrastructure are not addressed solely by grants in the three areas listed in the GAO report. Through the years, many, many more students have been supported by research assistanceships provided in the budgets of individual project grants than by formal training grants. Also, individual project grants often provide for equipment purchases although admittedly only rarely for large pieces of equipment and hardly ever for construction or substantial renovation of facilities.

There is very little institutional support coming to our universities in association with the collection of individual project grants. In fact, the cognizant A-21 circular of the Office of Management and Budget on cost accounting principles for colleges and universities has systematically denied to that community anything equivalent to the institutional research and development funds routinely made available to industrial contractors of the Federal Government. On the other hand, both program and center support very likely could tacitly provide for some institutional support, particularly for summer salaries and other initiation expenses for young faculty.

Given all of the above, I am going to presume to add another category of funding mechanism to the list in the GAO report, namely a hybrid.

VII. Individual project support combined with appropriate grants for training, equipment and facilities, and institutional support

There is nothing new or novel about this latter suggestion because, of course, it represents to a significant extent how we have done business through the last four decades--not adequately, I would suggest, but nevertheless the principle has been there.

We now have seven categories of funding mechanisms generally paralleling the categorization of the GAO report with the liberty of the addition of the hybrid. I have also given you a checklist of six desirable attributes, with some subdivisions, for the health and quality of any campus based research program. Now here are some opinions of the effectiveness of the several funding mechanisms assessed against that list of identified attributes.

Individual Project/Principal Investigator Support

This is the dominant mode of support by Federal agencies of the engineering and science research by faculty on our campuses, with argiculture probably being the notable exception. Through a number of government agencies the typical award to faculty members is based on evaluation of unsolicited proposals. Those proposals are professionally reviewed, sometimes by elaborate peer review processes, sometimes largely by the professional staffs within the agencies (ONR and some branches of AFOSR). The area of research and the specific line of inquiry is proposed by the individual faculty member, although judgments exercised in the review process obviously always have an impact on the combined thrust of the research supported by a government agency.

Under this mechanism the agency can be responsive to proposals in very broad fields, for example, chemistry, astronomy and mathematics. But if appropriate, the agency can be particularly receptive to proposals in certain areas like properties of simple liquids, solutions to a certain class of differential equations, etc.

This type of mechanism is particularly flexible and adaptive to starting research in new areas. Any investigator is free to put in a proposal for a new topic or a different type of experiment. This proposal still has to pass the review process, and the faculty member therefore has to be sufficiently persuasive in proposing the work to convince agency officials and those involved in peer review that proposed new endeavors make sense. One does occasionally hear complaints that the review process is too stodgy to recognize the brilliance of a proposed new line of inquiry, or principal investigators have been known to complain that the review process requires them to seminal new ideas before the funds can be made available to prove them out. Both of the preceding are probably occasionally true, but I have not heard extensive objections on this account.

Perhaps as a corollary to the rapid adaptation to new ideas this mechanism is very effective in the establishment of young faculty as independent principal investigators. If a faculty member in his first two or three years of appointment at the university can convince an agency to support his or her proposed work, this minimizes the chance that the young faculty person becomes beholden to a more established investigator. That minimizes rancor over credit for the results, particularly if that is a critical element in a tenure decision for the younger person.

The principal investigator project support provides maximum flexibility for adaptation of budgets to expenses peculiar to the proposed investigation. Such support devices rarely pay for the cost of elaborate instrumentation or facilities but can be reasonably responsive to modest basic instrumentation. This is also a means by which graduate students can be supported and, very importantly, provision made for the support of the principal investigator during the summer months.

Over the years, the university community and the Federal Government have worked out reasonable rules for recovery of indirect costs incurred in the pursuit of research by the collection of principal investigators on a given campus through overhead or indirect cost rates figured as some percentage of the direct cost of research. I know of no university that is recovering all of the costs caused by the various government programs on its campus, but it is generally agreed that those mechanisms basically allow equitable recovery of a perceptible fraction of operating costs. As alluded to before, this has turned out to be a non-responsive mechanism for the eventual necessary upgrading of equipment, renovation of facilities, and the occasional construction of new physical plant.

This mechanism of principal investigator project grants and contracts can provide for long-term stability of support. Grants are normally for a definite period of time, typically one to three years, subject to renewal or extension based on a fresh proposal. I know of many principal investigators who have kept research programs going without interruption for several decades with support from the same agency or mixture of agencies based on periodic resubmission of proposals for ongoing research.

But support can equally easily be discontinued, if new proposals are not submitted or if the results of the research reflect a lack of freshness and imagination, particularly when placed in juxtaposition to competing proposals for new and innovative work. The system is one of acute competition.

This mechanism is one that has almost built-in assurance of support of nothing but quality research because of that fierce competition for funding individual project grants. However, the balance among the various disciplines within the portfolios of the funding agencies is less clear, and there are clearly subjective judgments leading to distribution of funds within the directorates or disciplines. For example, I am easily persuaded that the National Science Foundation is supporting nothing but quality work in both the areas of chemistry and mathematics. But it is less clear to me that the distribution between the two fields is the best possible. Furthermore, most agencies do not seem to have mechanisms in place to assess that question very aggressively.

I have already stated that the individual principal investigator project grant is a poor way of addressing the problems of equipment and facilities. It has turned out to be a very effective means of supporting graduate students through graduate research assistanceship appointments.

Finally, the individual principal investigator grant mechanism is a rather weak tool if an agency is attempting to foster cooperative or concentrated research in a given area.

In summary, and on balance, it is my opinion that the program of individual principal investigator project grants and contracts has had a long record of great success in the support of programs in science, and that it should remain the dominant mode for the support of scientific research on our campuses. It should also be the principal mechanism for the support of engineering and applied research; although, as I will discuss in a moment, I think there is a role for project and center support in these areas when an agency is attempting to force or encourage collective inquiry on certain more applied topics.

Project Support

In this context, we are using the descriptor of "project support" to identify the collective activities of several faculty members with related research interests. When a grant is awarded to cover the joint activities of several investigators, there occasionally may be some elements of flexibility not present in the funding of the principal investigator grants. The support of graduate students or research assistants is one example, as is support of technicians for maintenance of a computer facility, centralized spectrometer usage, etc. Effort invested in proposal writing and subsequent technical reporting might be less than would be required for a collection of principal investigators engaged in the same activity. Since this is presumably a less formal structure than the center project, which I will discuss in a moment, one presumes that there is a minimum of internal administrative structure. There probably would have to be a project director who would have the lead responsibility for dealing with the funding agency and serve as a convenor of the campus working group. However, that individual presumably would not have a strong hand in planning and directing the detailed research activity of the colleagues in the project.

This might be a particularly helpful format to assist a young faculty member starting his or her research program, assuming that project budgets were adequate to provide for summer salaries of several such young investigators, support of graduate students, and other necessary expenses. It probably also is attractive to young investigators because of the possibility of reasonably independent work.

From the viewpoint of the funding agency, the project may be a gentler tool in an effort to get research focused in a particular area. Some degree of concentration on a common theme could be encouraged but stopping short of the sharper focus usually associated with a center.

Center Projects

The center presumably goes significantly beyond the program support, both in internal administrative structure and also as a strategy of guiding most of the research within prescribed channels. Overall, this makes it possible to respond to some agreed upon areas of concentration as worked out with the funding agency. As mentioned above, it is not uncommon for faculty to identify themselves informally as a "program" for purposes of graduate recruiting and efficiency of proposal preparation. On the other hand, from my observation, it is relatively rare that a university on its own will create a center in the sense described here unless there is a stimulus from an external source, for example, a requirement from state government, availability of funds from a Federal agency, etc. In the extreme, the center concept is antithical to the principle that faculty members and senior graduate students should be free to pursue lines of inquiry suggested by the research itself. Therefore, in general, I think the center concept is particularly inappropriate in most instances for support of science research on our campuses.

On the other hand, our engineering research community can and should be putting some of its capacity into larger scale research endeavors. On selected topics ranging from circuit design, to dynamic response of large structures, to safety strategies for chemical plants, research often benefits from parallel efforts from several groups on a given campus. Occasionally, the program can be significantly aided by real-time cooperation with one or more industrial laboratories or a laboratory of the Federal Government. The latter interaction can and should involve exchange of personnel and on occasion can provide access to critical equipment that is too expensive to be constructed on a university campus.

Therefore, when a funding agency senses a need for increased research activity in an applied area, there is clear merit in establishing and maintaining an appropriate center on a university campus. Assuming the university has or is able to assemble the necessary number of faculty, graduate students, and supporting professional staff, this mechanism can foster a concentration on a particular subject that probably would not happen if the faculty pursued their individual projects. The involvement of personnel from industry or national laboratories can augment the educational experience of the graduate students in the program and at the same time assist in a much more rapid transfer of the new knowledge and techniques to the technology base of the nation.

But I would advocate centers in moderation and only when the funding agencies are confident that they have already paid adequate attention to the research in the normal disciplinary areas. The center mechanism can work well when it is possible to call on distinguished faculty members from established programs in electrical engineering, computer science, mechanical engineering, structural engineering, etc. In fact, I personally believe that no center should ever have the right to make faculty appointments, admit graduate students, or award degrees. These should be the responsibility and prerogative of strong disciplinary departments.

The center is a particularly effective way for providing support for graduate students since the budget for the program can include a number of research appointments that can be used much more flexibly than the similar appointments in the budgets of individual project grants. A well run center can be the locus of a very exciting educational experience for an M.S. or Ph.D. student in engineering. A sense of shared goals, team participation, interaction with an external constituency in industry, a sense of awareness of the interest from the funding agency all are snapshots of the real life of engineering research that the students are headed for in their future careers.

On the other hand, I have mixed reactions about the centers with respect to young faculty members starting their careers. The center may provide an extraordinary opportunity for the faculty member to have summer salary support, immediate access to supported graduate students, availability of equipment that would otherwise take years to assemble, and an immediate working relationship with senior colleagues. In all of the above, there is also a potentially lethal trap. We expect our junior faculty members to present records of independent accomplishment at the time they are considered for tenure, which is typically no later than when they enter their seventh year on the university campus. However, service as an assistant director on a project will usually not be an adequate substitute for a record of scholarly publications. Even if there are a number of papers but the junior faculty member is co-author with a more senior faculty member on the project, there will be the inevitable questions about the balance of credit for the new ideas. Overall, there is a pervasive concern whether the younger faculty member has established himself or herself as an independent investigator. I have seen too many cases of young faculty members' careers ruined by immersion in the administrative affairs and the mechanical operations of larger scale projects. These circumstances are further lamentable if the young faculty member has been coerced into the project by a heavy-handed department chair or dean trying to demonstrate to the funding agency that the project was adequately staffed.

There can be other personnel problems with projects. Universities will tell you very firmly that the project should never be started unless there is a reasonably convincing commitment from the funding agency to provide stable funding over a number of years including adequate notice if there has to be a turndown or discontinuance in the program. The university, on the other hand, is in a weak position to provide assurance of ongoing participation by any given set of faculty individuals. It is the nature of our university setting that participation in such projects by faculty members is voluntary, and faculty members may come and go. As with many other endeavors in life, these projects tend to work best when there is initial inspired leadership from an individual who then sticks with the undertaking through at least its formative years. In this whole matter, I think there is a rather cloudy issue of whether the responsibility for the success of the project is really that of the university, the school of engineering, or at the level of an individual or small group of individuals who prepares the initial proposal to the agency. Whatever the answer to that question may be, it is clear that the university in general is not able to exercise line authority over its faculty in the same way that industry or national laboratories can do with professional staff. More the reason that the center should always be regarded as an add-on to a strong disciplinary based structure, should never be more than a small fraction of that structure, and both the funding agency and the university should have the courage to give up the endeavor if key founding personnel drop out and there are not obvious replacements.

The center funding mechanism also obviously provides a very effective mechanism for purchase and maintenance of equipment, even devices of reasonable expense. It does not, however, generally treat the problem of maintenance and renewal of facilities. In general, it is as fair as the collected individual project grants in providing for indirect cost recoveries. The center may be a little more effective in de facto institutional support since it is possible to bury in large project budgets tacit support of items that would not get taken care of in the collection of individual project grants.

Training Grants

There have been several experiments with training grants, but the only program that has persisted for many years is that of NIH, and it has been particularly effective. Those NIH training grants seem to give biology departments and other administrative units flexibility to recruit graduate students and then place them with the faculty members as areas of interest are matched, with a minimum of some of the force-fitting that goes on when the dominant source of support is the collection of research assistantships in individual project grants. Clearly, NIH put the major training grants in institutions that had large, broad-based programs of principal investigator support from the NIH. This is, I think, a very significant point; namely, these funds were a complement to the individual project support program. In my view, it would be a serious mistake to sprinkle training grants around on an independent basis without assurance that recipient institutions had in place substantial research capability.

Facilities and Equipment Grants

My briefness here may be in inverse proportion to the significance of the funding mechanism, but I hope the message is obvious. None of the three mechanisms discussed previously for the direct support of research provide adequately for purchase and maintenance of equipment, renovation and construction of new facilities, and for systematic rehabilitation of facilities used for ongoing programs. One result is that the investment made by the funding agencies in direct support of research is often less than optimally used because we have some of the best minds in the country in the form of graduate students and faculty carrying out research programs on inadequate, antiquated, poorly maintained equipment and computer systems. Federal agencies occasionally have provided programs of special one-time funding for construction of facilities or major equipment purchases, and the community has nothing but applause for those endeavors, including several that are current. What is needed, of course, is systematic attention to this problem. There also needs to be assurance that when available, the equipment money goes to the support of the ongoing programs and is not spread too thinly over embryonic areas. We are not opposed at all to new endeavors, but a sensible long-term strategy calls for something approaching adequate comprehensive support for ongoing programs before new ones are initiated.

Institutional Support

All major universities invest a large amount of institutional funds in the initiation and support of research programs. This includes provision of facilities, support of faculty salaries, support of graduate students, support of the administrative structure, and many other features inherent in the system. It is clearly a matter of political judgment how much cost sharing should be expected from the individual universities in support of our research programs. I am not here today to advocate any particular distribution in that regard. But I do know there could be a very high return on modest amounts of institutional money awarded to universities but, in turn, restricted to the support of the ongoing research program. The Biomedical Research Support Grant program is a good example of this, but, as you know, funding for it is being zeroed out this year.

We particularly need funds to start young investigators, do institutional recruitment of graduate students, provide for purchase and maintenance of essential basic equipment, and for standby financial assistance when an established investigator is temporarily caught short of funds because of fluctuation in grant cycles. I personally find attractive the concept of a few percentage points of direct cost made available for institutional research and development somewhat parallel to the allocations made available to commercial firms. This is not totally popular since it is one more pressure on the indirect cost rates. However, this would be one element of overhead that the principal investigator community could accept more easily than some of the recovery for costs incurred.

Any program of institutional funds appears to a funding agency to have possibly less near-term impact on the output of research than principal investigator awards or even center grants. Since the purview of this task force is the long-term health of the scientific enterprise on our campuses, I feel free to suggest that there needs to be expressions also about the continuity and long-term success of the collected science programs on our campuses. We are living off of our capital, and some future generation of public servants, university administrators, and, above all, practicing scientists will properly belabor us for it.

Hybrid Support

My preceding remarks should have set the stage for the argument for the reasonableness of a strategy of mixed support. I am persuaded that the best science is probably done through the individual principal investigator project mechanism in the sciences and for most of engineering. But that mechanism provides poorly for institutional support for major equipment purchases, construction and renewal of facilities, and somewhat mixed results in support of graduate students. Although these latter shortcomings can and on occasion have been responded to by supplemental institutional grants, generally, these should be awarded in roughly direct proportion to the volume of project support being carried out on the campus. For a modest amount, that might be a sensible and efficient way to handle some support of graduate students, equipment of modest size, and general institutional support. I would suggest that major equipment purchases, construction, and renewal of facilities should be the subject of independent proposals with an appropriate review process.

Other Mechanisms

There is one other category of funding that occurs to me that warrants comment, namely, the support of large centers. Above a certain size, cost of construction, and cost of operation, the nation can only afford a limited number of certain types of facilities be they computers, linear accelerators, ground-based astronomical facilities, space telescopes, etc. Facilities have been constructed with funds from numerous Federal agencies including the National Science Foundation, and have been operated under various management arrangements. I advocate that universities always have a substantial influence on the decision to build such facilities and on their operation whether located at a single institution or managed by a consortium of our research universities. It is essential that the management structure also be augmented by a user's committee that has a real substantial impact on the development of instrumentation and allocation of research time.

I particularly comment on these types of facilities because I think on the one hand that programs such as the national observatories at Kitt Peak, major accelerator facilities at Brookhaven, Batavia, and on the Stanford and Berkeley campuses have been very successful and managed well towards meeting initial objectives. We are now also committed to the construction of super computers on five of our campuses. Do I think, therefore, that this might be a solution for much more of our science and engineering research, namely, clustering efforts on related topics in a few major facilities around the country? Emphatically not. The strength of our operation comes from diversity, competition and free choice. When we have no alternative but to send our faculty and graduate students to the large fixed facilities, of course, we will do so with appreciation for access to the experimentation that would not otherwise be possible. But it needs to be noted that this is at some expense, namely, a largely absentee faculty and graduate student population. Graduate students thereby miss a great deal of the collegiality and intellectual stimulation that comes from being part of a physics department, chemistry department, etc. and the broader university community.

Summary and Recommendations

I have tried to collect my assessment above of the several funding mechanisms into Table I in a format that gives a rating of each mechanism against the several desirable attributes of research that I laid out previously. Judgments are clearly idiosyncratic and will surely be disputed by many in detail. Nevertheless, the checklist may be useful and the format an interesting one for trying to get an overview of what should work well and for what reasons.

What might we conclude? Certainly that Vannevar Bush was perceptive and persuasive in his argument that the resources of the nation should be brought to bear in the establishment and support of a national program of pure and applied sciences largely located within our universities. Congress, through its wisdom and authority, has provided authorization, appropriations, and oversight; agencies have constructed and experimented with various programs; and the university community has responded, I believe, magnificantly in creating a system of joint research and training that is the envy of the rest of the world. I am personally persuaded that two of the reasons for success have been diversity and competition among agencies of the government to foster and support quality programs and competition among the universities, to compete for the best of graduate student and faculty talent, and to compete openly for the various forms of research support. We have reason to be collectively proud for a job well done in the best interest of the nation. Certainly there are defects, shortcomings, problems, and opportunities to improve. The scientific community and the nation recognize that is why the House Task Force on Science Policy has undertaken its current review. It seems indeed proper to pause and ask if the programs, techniques, processes and levels of appropriations that have served us well for the 40 years since World War II represent the best strategies to take us into the early years of the 21st Century.

Specifically, with respect to funding mechanisms, I believe that overall our recent and current mechanisms and processes are sound and should not be the subject for radical change. It would be my recommendation that as we move forward that the dominant mode of support should continue to be the individual principal investigator grant and contract awarded in open competition in response to proposals. Particularly in the area of basic sciences, this will assure generally the best quality research, the quickest response to new opportunities for research, the best assurance of shifts away from low priority areas, an absolutely first-class mechanism for rapid placement of young faculty in the system, and a very important form of stable support for graduate students. That overall program has been weak in providing for current quality instrumentation, renewal of facilities, and construction of new plants. As administered, there has also been a shortfall in any increment of institutional support targeted for reinvestment in the campus research enterprise. That is why I have advocated what we have labeled here as the hybrid approach, namely, dominant support coming through the individual principal investigator grants and contracts but with supplementation to the institution both by formula and also in response to proposals for some increments of funds for acquisition and maintenance of equipment and for construction and renewal of facilities. Supplemental programs of training grants are generally regarded as having contributed to the enhanced quality of Ph.D. programs in our major universities but only when available on a long-term basis.

Upon reflection, I find myself rather indifferent to program support. This rubric may offer some efficiencies in proposal and report writing, modest efficiencies in campus administration of funds, and some desired flexibility in the support of graduate students. There is the possibility of early support for young faculty members with the concurrent danger of entrapment in the research endeavors of senior faculty rather than development of independent areas of inquiry. My sense is that the agencies ought to be selectively responsive when principal investigators from a given campus submit joint proposals labeled as a "program," but I would think it a mistake for the agencies to divert substantial funds from the principal investigator mode in order to try to foster such program endeavors. In other words, if something good comes forward on its merit, support it, but do not try to force-fit this mechanism on our campuses.

The center concept is even more structured than the program. But except for very rare circumstances or opportunities, it is my opinion that the center concept should not be avidly developed as a means of supporting basic science research on our campuses, nor should it become a substitute for the dominant body of principal investigator support in the areas of engineering and more applied activity. But there is a place for centers in limited and controlled amounts when there is mutual agreement between an agency and the campus that a group can be advantageously brought together to concentrate student and faculty efforts, equipment and facilities, and total intellectual capacity on a particular inquiry or the development of a technology. In general, these centers will not provide the assurance of quality that is inherent in the collected principal investigator review processes for the awards. But I believe there is general acknowledgment that gains in concentration can be traded for the strictest level of competition and quality control. Centers provide very flexible means for supporting graduate students and generally would make it possible to acquire equipment of modest expense and probably maintain it much better than is generally done on our campuses. Such programs provide a quick means of assimilating young faculty into an active research career, but, on balance, represent a very treacherous career trap for a faculty member committee ultimately that tenure and a permanent career is justified. Attaining the community goals of the center as agreed upon with the agency probably may be generally deleterious to the establishment of a reputation for intellectual independence.

There is one other ongoing problem with respect to centers, namely, stability and continuity of research. You would certainly find me, as a current campus administrative officer, arguing that any center we established on our campus ought to carry from the funding agency assurance for reasonably long-term support, subject to appropriate review; also, agencies generally understand that the applied objectives cannot be met except by sustained activity. On the other hand, personnel at the campus level come and go. But more importantly, fields of interest wane and new opportunities present themselves. There is, therefore, real need for mechanisms that provide extraordinary vigilance with respect to the currency, relevance and quality of research carried out under the center mechanism, and we need the institutional courage to redirect or even stop when the operation has been passed by.

In closing, gentlemen, I have appreciated the privilege of appearing before you this morning, and want to leave you with several summary thoughts. The ability of the United States to compete economically and industrially in the international market place is an unequivocal national goal. Not only must we be a participant in that arena --I suggest we must win. As in most competition, coming in second is really losing. If we are serious, as serious we must be, then let us behave consistently and assure we attend to the fundamentals--the training of skilled personnel, and the flow of science and engineering research without which there will be no new technology. I urge the Task Force to endorse a continuation of the best science research and education establishment in the world. Above all, please pay attention to the infrastructure. The best minds of our society deserve better than we have provided for them in the way of facilities, equipment, and general support.

Assessment of Research Funding Mechanism

	Support Ph.D. Programs in Science	Support Ph.D./M.S. Programs in Engineering	Support Young Investigators	Career Development	Qual'ty Research - Science	Quality Research - Engineering	Response to New Opportunities	Discontinuance of Low Priority Programs	National Needs			Stability for Students/Faculty	Infrastructure
									Personnel	Transfer of Technology	Interaction with Industry/Government Labs		
I PI Grants	P+	P	P	P	P+	P	P+	P	N	N	W	P	W
II Program	N	N	W	N	N	N	N	N	P	P	P-	N	N
III Center	W	P-	W/D	W	W	N	W	W	P+	P+	P+	N	P-
IV Training	P+	P	P	-	N	N	N	N	N	N	N	N	N
V Equipment	P	P	N	N	P	P	N	N	P	P	P	N	W
VI Institutional Support	P+	P	P+	P+	P+	P+	P++	N	N	N	N	P	P+
VII Hybrid	P+	P+	P+	P+	P+	P+	P+	P	P	P	P	P+	P+

P	Positive
N	Neutral or Not Germane
W	Weak
D	Deleterious

DISCUSSION

Mr. **Stallings**. Thank you, Dr. Pings. We appreciate your comments. Let me ask a couple of questions.

In conducting their study on funding mechanism, GAO found that all of the institutions surveyed believed that the availability of seed money was critical to upgrading the research programs, yet we are providing less and less of this type of support to our research institutions. Do you have any information to indicate that adequate funding of this nature is available, either from Federal or alternate sources? Or, are we to conclude that colleges and universities who do not currently have significant research programs will continue to experience increasing difficulties in upgrading those programs?

Dr. **Pings**. Mr. Chairman, I do not have any explicit data to submit to you this morning on that matter. My experience is anecdotal. But, based on what I know from the institutions where I have served and from extensive discussion with colleagues in other universities and in associations, I believe we are very definitely hurting in the major institutions with established programs for that seed money.

We struggle mightily to start young faculty in their careers. It is a very significant cost to establish a young experimentalist in physics or chemistry or biology. It is not uncommon for the dean to come to me with needs for a half a million dollars to outfit a laboratory and put instrumentation in, to put someone into a career which you hope is going to succeed but often, sometimes, does not.

We scrape from various sources to find those funds. We try to get it from gifts. We try to get it from institutional funds. Sometimes we are not able to respond and sometimes we are limited in the number of younger people that we can appoint because of the scarcity of those funds.

It is not just young faculty. Our established investigators often are deterred or long delayed in starting a new line of inquiry because of inability to get a particular piece of instrumentation, or because their facility has begun to erode.

Many of our campuses do have information on the amount of money they spend on that and I think that has been or can be made available to the committee.

Mr. **Stallings**. As the Government's role in this has decreased in the last few years, have you noticed an increase in private or corporate grants for similar research projects?

Dr. **Pings**. I think there is an encouraging trend of industry coming—I think—back into more significant support of research on our campuses. And it is a good outcome because it not only is a source of funding—sometimes dollars, sometimes equipment that can be made available—contributed to the university or made available at the industry's location where they have expensive equipment.

Sometimes it is in the form of personnel that the company will share with an ongoing research endeavor—or a consortium of companies will share.

It is important, but when added up, it is a small fraction—I believe, at most, 3 percent of the total funding that is flowing from the Federal Government.

It is welcome. I would hope it will increase. I think we have—particularly in the engineering areas—a better research program because of that involvement.

I do not see any indication that it can or could become over night, or even over a longer period of time, a massive substitute for the system as we have developed it.

Mr. STALLINGS. Do those private or corporate grants come with strings? I mean, do you have to do research in specific areas that they demand or require? Or are you free to go in whichever direction you would like with those?

Dr. PINGS. Well, the arrangements are usually between consenting adults and it depends on what is put together, but most campuses are very careful about getting into arrangements that have too many strings that would have any restrictions on open inquiry on the campus, would give the corporation or the consortium of companies proprietary results, prior control of publication.

But, often the research will be in response to a proposal—as it is to something we submit to the Office of Naval Research or the National Science Foundation. It will be in an area of broad interest to the corporation.

It is a good arrangement. The universities will attempt to do the basic science, bring along some of the developments in applied work, then hand over the results to the broad industrial community to do the development and take the product to the marketplace.

Mr. STALLINGS. You indicate that only 100 of the 3,300 colleges and universities in the United States have significant research programs—which account, by the way, for 60 percent of the basic research performed in the country. What type of funding mechanism would be the most successful in building research programs in some of these other universities?

Dr. PINGS. Unequivocally, initiation is best done—in my mind, my opinion—through the individual project grant and contract. Again, I would urge that there be supplementation of some type that would provide for instrumentation. A young faculty member or any faculty member getting started, or an institution that has not had a long tradition would have a particular handicap in way of access to basic instrumentation and therefore, cooperation with a Federal laboratory can often be helpful to local industry.

But I would think, rather than block grants, letting the competition sort this out and individuals submit their proposals—in fact, again, that is one of the strengths of the system nationally.

I may sit here and tell you, basically, it is the facts as shown in the NSF reports, that it is an outcome that most of our research is concentrated in that small subset. Be that as it may, any individual faculty member anywhere at those 3,300 institutions is free to prepare a proposal and if what is put forth is of quality, the agency will gladly step forward and support it.

Mr. STALLINGS. In your experience over the last several years, has there been cross-communication between the universities? I am wondering if we are having—with 100 different universities doing research projects—what are the chances of two or more institutions working on, essentially, the same program and coming up with essentially the same results? What I guess I am asking is, is there dialog between the universities to say, "We are working on this particular project," rather than have another school do exactly the same thing?

Dr. PINGS. Well, if they are working on the same project, I hope they do, indeed, come up with the same results. And sometimes, that is all right. There is confirmation and needed confirmation, frequently, in the area of fundamental research. A very important experiment often needs to be confirmed.

Basically, it is a process of intense competition. That competition is fostered through the research grant proposal mechanism. I have already alluded to it. It is also very apparent in the process of putting papers into the journals and getting them reviewed and the individual getting proper credit for the work that they have done.

We see each other at many national meetings, the Gordon Conferences, international meetings, and the telephone bills are expensive. It is a dynamic, open system. We generally know rather narrowly what our colleagues and competitors at another institution are doing—although they will be a little bit circumspect when they are getting near to a result they want to get rushed into the literature.

Mr. STALLINGS. You recommend continued reliance on individual project grants and the use of center grants only in unusual circumstances. However, you also candidly observed that your own background has been almost entirely in large, well-known universities—Caltech, Stanford and such—which are known to be highly successful in attracting project grants. The Congress is interested as a matter of policy in encouraging quality research programs in the second and third tier of universities. Do you think that center grants would be more effective for that purpose than individual project grants?

Dr. PINGS. I would be dubious until any institution had established its disciplinary base. Quite frankly, I do not think you will have a very high chance of success in a center grant at any institution in an applied area, say, that cuts across new techniques in fiber optics communications unless you have in place the basic areas of physics, electrical engineering, and computer science. If those individuals are there, if the disciplinary base is intact, there is a means of recruiting and appointing and testing the qualities of faculty members as they come along, of recruiting quality graduate students into those programs, then I think those faculty members can aggregate and perhaps, then, recruit some additional colleagues to form a major program or a major center.

A top-down imposition of a center—whether enticed by availability of State or Federal funds or as devised by university administration—is, in my view, based on experience, likely to fail because it will only very slowly develop the necessary personnel with a strong disciplinary base.

Mr. STALLINGS. You cite that the individual project grant is the funding mechanism most likely to support a new line of inquiry. Does not that project selection mechanism frequently mitigate against this possibility? What percentage of individual project grants are awarded for innovative programs or ideas? And has that percentage increased or decreased over the last several years?

Dr. PINGS. Mr. Chairman, I do not have any available statistics with me this morning in that area and, again, my report to you will have to be anecdotal in response.

As I alluded in my direct comments to you this morning, I believe the contract and grant mechanism to the individual principal investigator is very responsive to new ideas. A young faculty member getting started is free to go ahead and do what he or she wants, regardless of what a senior professor in the department may think is important—and we have seen many careers emerge rapidly because of ideas and the availability of funding through that mechanism that will allow the individual to establish that line of research. So I think the mechanism is responsive in that regard.

The program or project or center is likely—or could be actually inhibiting. It can foster cooperative research in the extreme of a center in an agreed-upon area of inquiry and it has done so very successfully and, in our engineering schools, we have seen some very significant applied results come out of that. It may, on the other hand, be discouraging of an individual who suddenly wants to go off and pursue the results of some exciting measurements that came in yesterday that would suggest that there might be a new phenomena available. But that does not seem to be an agreed-upon description or statement of objective of what that center is about at the present time.

Again, it is the diversity of our system that I think that gives us the strength to respond in both areas.

Mr. STALLINGS. You have cited a particular need for funds for standby financial assistance when an established investigator is temporarily caught short of funds because of fluctuations in grant cycles. If individual project grants—which account for nearly three-fourths of our support of scientific research provide for long-term stability of funding—as you have also stated—why should such funds be necessary?

Dr. PINGS. The process is, again, one that is competitive. Investigators, even though they have been at the business for several decades, are required—probably on 3-year or at most 5-year cycles—to put new proposals in—and properly so. There should, in my view, not be any substantial lifetime funding without periodic critical review of the performance.

Once in awhile, for even the most renowned of the established investigators, those proposals will not fare well in the open competition and fair enough. They should not, in that case, be funded. Maybe it was a poor proposal. Maybe the idea, in fact, was so innovative it caught the review committee unaware. And, surely, if it is an individual who has been on our faculty for many years and has been supported in the overall program of university science engineering research or supported by the Federal Government, one failure or one stumble should not be a basis for that person's career to have stopped and we need to keep them going. There may be associated personnel such as postdoctoral fellows, graduate students, technicians that need to be sustained. So it is not uncommon for a faculty member to come to a department chairman or dean and say, "I need help through this summer. My grant has actually been renewed but the other one runs out in July, I need help through September." So that would be a type of bridging that I am thinking of.

I assure you, Mr. Chairman, that I am not thinking of support that would indefinitely keep gong someone whose career is really beginning to wind down and he is lacking fresh ideas, cannot really compete in the open marketplace any more.

Mr. STALLINGS. How good are devices for determining good research programs as compared to some that may be questionable? I am not familiar with the process of the selection, but if you have several young scientists making proposals, who makes the decisions and who determines which are the good proposals and which are the questionable ones?

Dr. PINGS. There are different mechanisms. Of course, the university has a first obligation to not even have a proposal submitted, whether it is to a Federal agency, an outside foundation, State entity, industry, unless there is a vouching for the general quality and integrity of the work and the credentials of the individual.

Once a proposal goes out—and whatever the entity is that receives it, has to review it—we have very elaborate peer review processes in some of our agencies, although they are different in how they operate. The National Science Foundation, the National Institutes of Health typically solicit the help of established investigators in the field to render a judgment. In the case of the Office of Naval Research—which sponsored some of my research for many years—that was done in-house by professional members of the staff who made it their career, sometimes seeking outside support but being competent to do it on the spot.

Mr. Chairman, it is a judgment process, but there are many indicators of quality in the work that is proposed and, of course, after an individual is going for awhile, there is an immediate test of, what have they done? Is the work of quality? Has it sustained the critical review when papers have been submitted? Have they been submitted for the literature? Have they been reviewed and published in the open literature?

And there are ways then to find out—if a person has been around a decade—whether the papers have been published or not. Does anybody care? Is anybody citing those papers in other work? And what are the credentials of the individual as measured by invitations to speak at national conferences of those such matters?

Again, some of that is judgmental and some of it involves established groups that, frankly, continue to call on the same people and one has to be careful of that. But I think particularly the agencies, the National Science Foundation and the NIH particularly, are very careful to see that the personnel involved in their peer review process turn over in a systematic way so, in fact, there is a balance between continuity of standards in that process but, always, new faces coming in so that there is an attempt if I send in a proposal this year and it fails and I am absolutely angry because I think it is the process that is defective rather than the quality, what I am proposing, fair enough, I can send it back in. And ocasionally it will catch a second time around.

Quite frankly, if I have it sent back I am sure I would rewrite it once before I resubmitted it.

Mr. STALLINGS. Do you think the system works?

Dr. PINGS. Sir, are you talking about this narrow review process now? Or the entire system of support?

Mr. STALLINGS. The entire system of support.

Dr. PINGS. Absolutely. And I think it is—as I stated in my testimony, I think it is the envy of a number of countries around the world that are committed themselves to the pursuit of research programs.

I do not know, really, if everybody had thought it out 40 years ago when we began to get on this track and have pursued it, the particular strength of it—and I believe unique for large endeavors, national endeavors—is the joint production of these research results while we are training the next generation of people. That has worked particularly effectively. I believe it has served the Nation very well.

Mr. STALLINGS. Have any other foreign nations picked up our system and are they emulating it? The Japanese or the Europeans following a similar program as we have?

Dr. PINGS. Mr. Chairman, I am not a student in depth of those institutions. I have visited some, including in the Soviet Union.

I see a move in England, I think, toward a hybrid system that is a bit more like ours as the time goes on. The university grants committee in that nation is setting up at least a bypass mechanism that provides modest but some funds that individuals can compete for openly, in addition to what is passed directly through the university.

In Germany, of course, the Max Planck Institutes tend to dominate this. In Russia it is the Institutes of the Academy—quite separate from what goes on at the universities.

I was told recently that, in many of the French research centers, they will stand in line to apply to get a recent graduate student from the United States trained in biology to come there as a postdoctoral fellow because it is known how well-trained and how well-educated those Ph.D. students are as they come out of our educational programs because they have gotten their research degree, if you will, by doing research in the context of well-developed apparatus.

Mr. STALLINGS. Thank you.

I am pleased to have our chairman with us this morning. Mr. Fuqua, do you have some questions that you would like to ask Dr. Pings?

Mr. FUQUA. Dr. Pings, I apologize for being late in getting here this morning.

Dr. PINGS. I understand.

Mr. FUQUA. Unfortunately, we still have not devised a way to be in two places at one time. But I am very delighted to be here and I have had a chance to review your statement.

I noticed you said that the brevity of it did not—and I am speaking of facilities—the brevity of your response was not anywhere in relation to the size of the problem. And I am wondering, how severe is the present system of funding research neglecting our facilities, both facilities and instrumentation? And, as a result of that, impact on the quality of research that we may be receiving?

Dr. PINGS. Mr. Chairman, it definitely is limiting. I did not endeavor to provide quantitative information in this area because I know the National Science Foundation and others have been gathering that information and have been systematically surveying enough of our major institutions that I am sure you will have made available to you a factual assessment in that arena.

We are doing less than the best in the training of those graduate students. I will boast about it. I still think it is an outstanding system. The question, I think, before us is, could we do a better job?

Of course we can always do a better job. It is well-known, that universities can always spend more money. That is never our problem. I think what we are really talking about here is consistency, is the massive investment that we have from these agencies at the level of billions of dollars per year multiples from the National Science Foundation, the National Institutes of Health, and the Department of Defense. Is that money being best applied? And should there be consideration of modest increments on top of that? Or even, possibly, a combination of some additional funds and some redistribution even within those funds to attend to the ongoing erosion of that infrastructure?

We often have graduate students carrying out measurements on antiquated equipment. We even instruct in our undergraduate laboratories on that basis, unfortunately. But it is limiting to the graduate student, to the young faculty member and we are occasionally failing to do research that we could, on a frontier basis, for the lack, particularly, of sophisticated instrumentation. That means we defer to industry and on occasion, that is quite all right. Again, it is open competition. It can be done somewhere else excellently.

What I particularly would deplore is, if we found ourselves slipping badly behind the other nations in the quality of that research because we have failed to provide for the facilities and the instrumentation. I think we are on the brink of that. And what I cannot really measure for you—and as you get your data you will perhaps be able to assess it—is to what extent, if this is really a ticking bomb, that we have put off, year by year, the repair of the leaky roof, the drains that do not work and the maintenance of the equipment we have.

There have been spurts of equipment money and facility money at times. We have taken advantage of it—and, I think, effectively so. And then there is a long lull, essentially, of decay as we live off those results.

Our faculty are very creative and I can tell you, as a dean and provost, I am aware of how clever our faculty are at acquiring equipment from their colleagues and from various sources and putting it to good use.

I would not want to thwart that innovation. But to the extent possible, if we could back it with a sensible infusion of funds for new instrumentation, I'd think the return could be significant.

Mr. FUQUA. Mr. Stallings asked a question. I would like to elaborate on it, about the—I will maybe phrase it a different way—in multi-disciplinary research and I think your response was that it is very important that the departments be established and not to use that to establish the department. But suppose that it was very good to establish it? He used three universities that are in your area, Caltech, Southern Cal and Stanford, say. They have, I think, reasonably good reputations. And suppose that you had the microbiology department of one and maybe the pharmacology department of one of the schools and maybe the dental school of one other, looking at a problem of gum disease or maybe you had other disciplines that could really support each other in multi-disciplinary approaches to problems. Now, it seems to me—and it has been brought before the task force by some other distinguished people who have shared their views with us—that this is one of the areas that the individual investigator tends to get away from, the fact that in society demands now that we go to approach many of the problems in a broader scale than we have in the past.

Maybe you could comment on that and I would certainly appreciate your views, based on your knowledge and experience.

Dr. PINGS. I agree. There are many opportunites to bring together people with peculiar training and experience and have them aqddress a common problem.

Now that you mention it, those three institutions, I can point out examples of that type of activity that is going on. There is a very large grant on the fundamental phenomena and problems of Alzheimer's disease that is being managed by a professor in the biology department in the school of gerontology at the University of Southern California that will involve also the medical school of the same university and the biology department at Caltech.

I recently have approved our participation in the joint research earthquake engineering proposal that is wending its way through the review process right now that would involve Caltech, U.S.C., Berkeley, and Stanford.

We have, with great enthusiasm, agreed to participate in the supercomputer center that will be at the University of California at San Diego.

So sometimes it is driven by a unique facility such as the latter—often by the aggregation of talents to address a problem of such scale that no one investigator or campus can do that.

And in all of the above and most I can think of, again, we are talking about distinguished faculty members, a relatively small number from those institutions, getting together because they see the possibility of addressing a problem and making progress on a shared goal.

I can assure you that—I referred to approving a proposal. I can assure you that that earthquake engineering proposal was not generated by vice chancellors and senior vice presidents for academic affairs at the various institutions thinking that it was a good time for their faculty to do that. The best joint efforts usually are ones that you suddenly hear about at the administrative level that your faculty have been quietly bootlegging through several years with a colleague at another institution or in an industrial laboratory.

I know that if I try to keep that sort of thing down, I probably am doing what I can that is best because it will surely, then, pop up and will then come forward on its merits. It is the duty of the university administration, when that potential is there, to then reach out and see if we can provide the joint agreements and the infrastructure to support it and, where we can, at that point, intervene and be an emissary to Federal agencies or sometimes then, a corsortia of Federal agencies that might provide that support.

Mr. Fuqua. Well, and maybe even industry.

Dr. Pings. Yes.

Mr. Fuqua. Well, you can think of many of them, but suppose in the area of acid rain, that involves not only the chemistry but also of properties that are being put into the atmosphere and it involves the astrophysicists and a lot of other people that have a field of expertise. And the disposition of toxic wastes, a very important issue in this country. It seems to me that it involves a lot of disciplinary talents to address the broad scope of the problem, rather than just some narrow parts of it, even though that is important.

And I think, in talking with some of the people in industry, they have suggested that the industrial perspective over some of the research now is much broader today than it has been, maybe, in past years because of elevated concerns about the impact that certain things may have, particularly in the petrochemical industry, when we are very concerned about the effects on human life and residual impacts.

So it has been pointed out several times that this was an area that some felt had been neglected in our single investigator type of approach in many of the agencies.

Mr. Chairman, that was all I had.

I want to thank you very much, Dr. Pings, for being here.

Dr. Pings. You are very welcome.

Mr. Stallings. Again, Dr. Pings, we would like to thank you for your time and your testimony. Your information has been very helpful to this committee and we do appreciate your expertise in this area.

Dr. Pings. Thank you.

Mr. Stallings. With that, we stand adjourned.

[Whereupon, at 9:35 a.m., the task force recessed to reconvene at 8:30 a.m. on Wednesday, March 19, 1986.]

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RESEARCH FUNDING MECHANISMS

WEDNESDAY, MARCH 19, 1986

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to call, at 8:30 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. Fuqua. This morning we begin our third in a series of four hearings on research funding mechanisms, and we're very pleased this morning to have Dr. Carl Douglass—if you'll come forward, Dr. Douglass—former director of the Division of Research Grants at the National Institutes of Health.

Good morning. We will be pleased to hear from you at this time.

[A biographical sketch of Dr. Douglass follows:]

Carl D. Douglass, Ph.D.

Dr. Carl D. Douglass was born April 27, 1925 in Little Rock, Arkansas. He received a B.S. degree from Hendrix College in 1947, and an M.S. and Ph.D. from the University of Oklahoma in 1949 and 1952, respectively. After receiving his doctorate, he held various positions in the Department of Biochemistry at the University of Arkansas until 1959 when he joined FDA as Chief of the Nutrition Research Branch. In 1961, Dr. Douglass joined the staff of the National Institute of Arthritis and Metabolic Diseases where he served as Nutrition Program Officer. During the period 1964 to 1967, he headed the Research Training and Facilities and Research Divisions of the National Library of Medicine. In 1967, Dr. Douglass became Associate Director of the Division of Research Resources at NIH. In 1970 he joined the Division of Research Grants of NIH where he held various positions until 1985, when he retired as Director of that organization, a post he held for some 9 years.

Over the past 20 years, Dr. Douglass has received numerous superior service and performance awards, and is listed in *Who's Who in America.* He has held membership in the American Chemical Society, the Society for Experimental Biology and Medicine, the American Institute of Nutrition, the American Institute of Biological Sciences, Alpha Chi Sigma, Sigma Xi, and Phi Lambda Upsilon, a fellow of the American Institutes of Chemists and of the American Association for the Advancement of Science, and has served on the Editorial Advisory Committee of *American Men and Women in Science.*

STATEMENT OF DR. CARL D. DOUGLASS, FORMER DIRECTOR, DIVISION OF RESEARCH GRANTS, NATIONAL INSTITUTES OF HEALTH, U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES, BETHESDA, MD

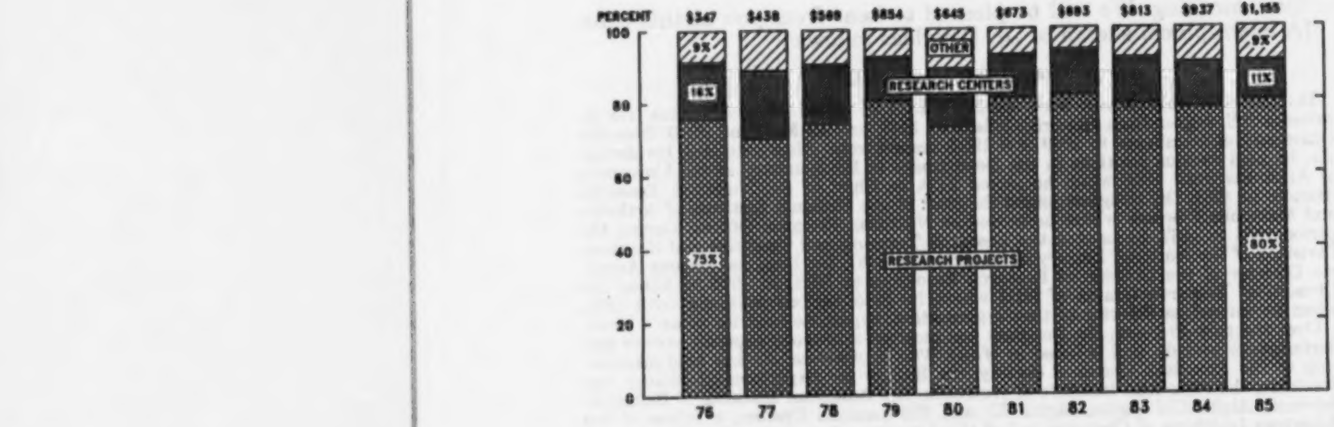
Dr. Douglass. Good morning.

My name is Carl D. Douglass. I'm pleased to be here this morning to speak to you about an issue which I believe to be of great importance to the Nation's programs of scientific research.

About 1 year ago, I retired from the Federal service. I spent the major part of my career in the administration of the principal health research program of the country, namely that of the National Institutes of Health. The last 9 years of my tenure at NIH were spent directing the Division of Research Grants, which is the primary focus for the receipt, referral, and scientific evaluation of research grant applications to the NIH, as well as to other elements of the public health service. My remarks today will reflect my experience at the NIH and my own personal opinions which have developed from my years there. These opinions in no way represent any official policy, position, or opinion of the NIH or any of its officers.

The project grant has been the principal instrument used to support biomedical research by the NIH since the inception of its program of extramural support immediately following World War II. It remains so and in recent years has accounted for about 80 percent of the funds committed to research support, as can be seen from figure 1 which I have attached.

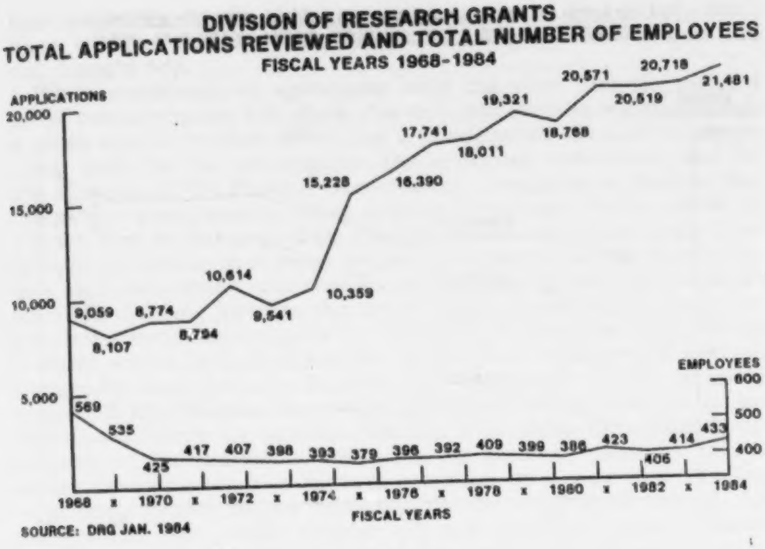
DISTRIBUTION OF NIH COMPETING RESEARCH PROJECT, RESEARCH CENTER, AND OTHER RESEARCH GRANTS, FISCAL YEARS 1976–1985 (CURRENT DOLLARS IN MILLIONS)



NOTE: SEE TECHNICAL NOTE ON PAGE III FOR ACTIVITY COVERAGE.
SOURCE: NIH, DRG, STATISTICS AND ANALYSIS BRANCH

Figure 1

As the population of biomedical researchers has increased, the number of applications seeking project grants has increased. Figure 2 demonstrates that quite dramatically.



DIVISION OF RESEARCH GRANTS
TOTAL APPLICATIONS REVIEWED AND TOTAL NUMBER OF EMPLOYEES
FISCAL YEARS 1968-1984

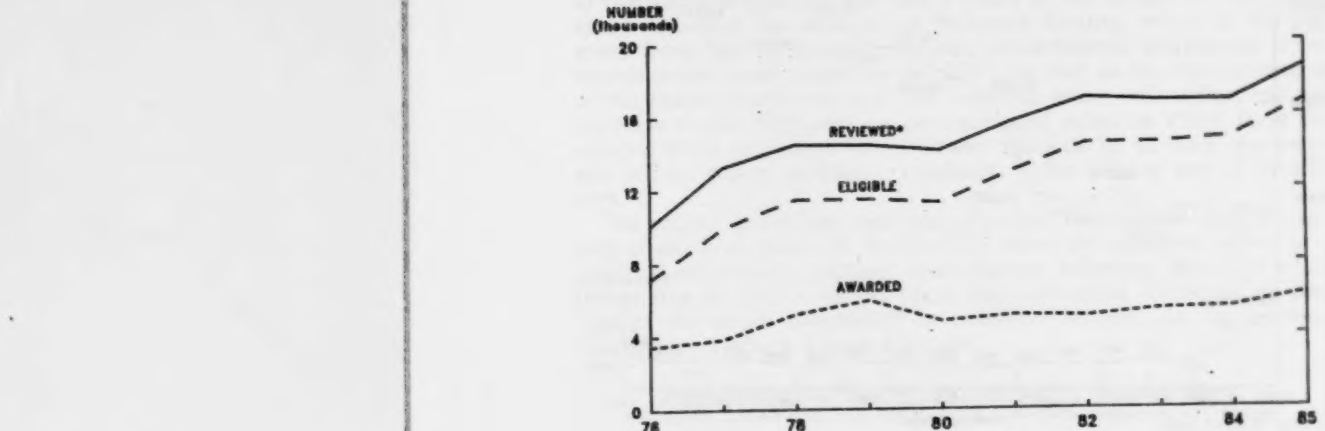
SOURCE: DRG JAN. 1984

Figure 2

I should note parenthetically that the actual number of applications shown on this chart overstates the number of research projects, per se, by 10 to 20 percent, because of some other types of applications which are reviewed by the DRG, but the increase, nonetheless, is very largely due to a project grant mechanism.

As this number of applications has increased, the ability to fund those meritorious applications which are eligible for funding has diminished very significantly, as you can see from figure 3, where the number of applications reviewed or evaluated has increased and the number awarded has stayed fairly constant.

NUMBER OF NIH COMPETING RESEARCH PROJECT APPLICATIONS REVIEWED, ELIGIBLE AND AWARDED, FISCAL YEARS 1975–1984



NOTE: EXCLUDES TQ. SEE TECHNICAL NOTE ON PAGE III FOR ACTIVITY COVERAGE AND PROCEDURES.
*REPORTING YEAR.
SOURCE: NIH, DRG, STATISTICS AND ANALYSIS BRANCH

Figure 3

With this very obviously heightened competition for available funds, there has arisen an understandable anxiety on the part of investigators and their institutions which has, in turn, resulted in their devoting increased time and effort to the preparation of applications and longer, more voluminous applications, and in more applications per investigator.

During the last few years, the length of the period of committed support—that is, the project period—has remained almost constant, at about 3 years. Concurrently, the Federal Government has laid on a number of administrative requirements related to such matters as the treatment of human subjects of research, the use of warm-blooded animals in research, increased financial accountability, et cetera. These, too, have added to the complexity of the process of preparing applications. Thus, the widespread apprehension that there is a disproportionate amount of time, effort, and paperwork occasioned by the extensive use of the project grant is more than justified.

The concern that the system of project grants discourages the conduct of high-risk research may be valid, but as far as I know, there's no objective evidence for it. I've heard many anecdotes alleging it and have dealt with many complaints in which the disappointed applicants have stated that the system does not tolerate the really bold innovative ideas. In most cases that I can recall in retrospect, these ideas, unfortunately, well deserve the treatment they got at the hands of the peer review groups. So I simply don't know whether this is a factor or not, and I don't know how to find out, I might add.

While completely in agreement with the view that the current set of circumstances has given rise to a situation in which there is a great deal of wasted effort and a burdensome amount of paperwork, both for the investigator, the applicant institution, and for the agencies of the Federal Government, I continue to believe that the project grant system offers greater advantages to the public, to science, and to the individual scientists than any other system yet devised. It assures that every project is subjected to individual scrutiny and peer review and that it, on the basis of the best available scientific opinion, justifies the use of public funds. It allows the individual scientist to compete on the national level free from the influences which may be operative at the local level, which in turn frequently have little to do with the true merit of the proposed project. It also assures that uniform criteria will be used in the selection of projects for possible funding. It provides for national recognition of the individual scientists, an absolute necessity in the career development of a mature scientist, in a way that funding from large grants at the local institution could never afford. Although the most recent figures are not available, table 1 shows that the project grant has allowed the newly independent scientist to gain support that is quite gratifying.

Table 1

National Institutes of Health

New P.I.'s on All Types of R01 Grants
Compared to Number of P.I.' on All Types of R01 Grants

Fiscal Year	All R01 Awardees	New P.I.'s	
		Number	Percent
1970	8,489	714	8.4%
1971	8,190	817	10.0
1972	8,403	1,117	13.3
1973	8,196	788	9.6
1974	9,220	1,425	15.5
1975	9,493	1,441	15.2
1976	10,483	1,138	10.9
1977	9,973	1,126	11.3
1978	10,617	1,443	13.6
1979	12,046	1,768	14.7
1980	12,607	1,301	10.3
1981	12,671	1,242	9.8
1982	12,114	1,008	8.3

RAEB/DRG
July 5, 1983

Parenthetically, I'd like to add just a little bit of a note related to the interpretation of this table. These are the traditional research project grants. They show the number of awards in that category that the NIH has made each year. You notice that in 1982, which is the last year for which I have figures, the number was about 12,000. About 1,008 of these went to brandnew investigators—that is, investigators who had never had any kind of NIH research grant support before. This has remained in that neighborhood for many years, as long as we've been keeping track of it—it's varied between 15 and 8 percent there, I see—in the average, about 12 percent, and I can elaborate on this later if anyone's interested.

Another concern that I feel about proposals to replace project grants with large center-type grants or with grants made on the basis of the reputation of well-known scientists, is that they will, of necessity, be made at a few existing large research institutions, and investigators at smaller, less well-known institutions will be placed at a great disadvantage in the competition for the very scarce funds now available or those likely to be available in the future.

Another problem with large center-type grants is the institutional dependence which inevitably develops, particularly in those instances in which they've been in place for a number of years. If the funding agency finds it necessary, either because of limited appropriation or because of the quality and productivity of the scientific work declining, to curtail funding, very frequently major individual, as well as institutional dislocations, will occur.

In summary, I think that the project grant should remain as the keystone of programs funding research. I also think that it is possible, with hard work and understanding on the part of all concerned, to modify and streamline existing procedures in order to simplify the application process as well as the processing of the applications by the agencies. This will decrease the current awful burden of paperwork.

I think also that the project periods could be lengthened, particularly for those projects of high scientific merit, in order to provide more funding stability for the investigator.

I should emphasize that I do not oppose the use of center grants in appropriate settings, but I do not think that such mechanisms should displace project grants as the principal support instrument.

It is also my firm conviction that the substitution of any system that eliminates competition, or even diminished competition, I might add, and substitutes some form of entitlement to funding will seriously injure American science and will result in large wastage of taxpayer dollars.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Douglass follows:]

COMMITTEE ON SCIENCE AND TECHNOLOGY
SCIENCE POLICY TASK FORCE

HEARING ON
"Research Funding Mechanisms"

March 19, 1986

STATEMENT OF

CARL D. DOUGLASS, Ph.D.

Good morning. My name is Carl D. Douglass. I am very pleased to be here this morning to speak to you on what I believe to be a serious issue related to this Nation's programs of scientific research. About one year ago I retired from Federal service. I spent the major part of my career in the administration of the principal health research program of the country, namely that of the National Institutes of Health (NIH). The last nine years of my tenure at NIH were spent directing the Division of Research Grants (DRG), the primary focus for the receipt, referral, and scientific evaluation of research grant applications to the NIH. My remarks today will reflect my experience at the NIH and my own personal opinions which have developed from my years there. These opinions in no way represent any official policy, position, or opinion of the NIH or of any of its officers.

The project grant has been the principal instrument used to support biomedical research by NIH since the inception of its programs of extramural support immediately following World War II. It remains so, and in recent years has accounted for about 80% of the funds committed to research support as can be seen from Figure 1.

As the population of biomedical researchers has increased, the number of applications seeking project grants has increased. Figure 2 demonstrates this quite dramatically. (Note: The number of applications shown on the chart overstates the number of research projects by 10% to 20% because some other types of applications are reviewed by DRG.) As this number of applications has increased, the ability to fund those meritorious applications which are eligible for funding has diminished significantly as shown in Figure 3. With the very obviously heightened competition for available funds, there has arisen an understandable anxiety on the part of investigators and their institutions which has, in turn, resulted in their devoting increased time and effort to the preparation of applications, in longer, more voluminous applications, and in more applications per investigator. During the last few years, the length of the period of committed support (project period) has remained almost constant at about three years. Concurrently, the Federal Government has laid on a number of administrative requirements related to such matters as the treatment of human subjects of research, the use of warm-blooded animals in research, increased financial accountability, etc. These too have added to the complexity of the process of preparing applications. Thus the widespread apprehension that there is a disproportionate amount of time, effort and paperwork occasioned by the extensive use of the project grant is more than justified.

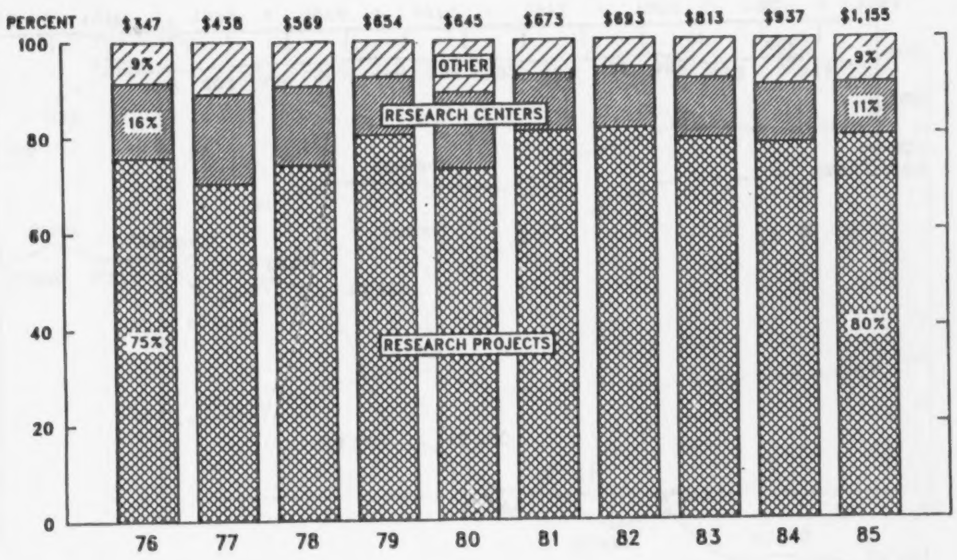
The concern that the system of project grants discourages the conduct of "high-risk" research may be valid, but as far as I know, there is no objective evidence for it. I have heard many anecdotes alleging it, and have dealt with many complaints in which disappointed applicants have stated that the system does not tolerate the really bold, innovative ideas. In most cases that I recall in retrospect, these ideas well deserved the treatment they got.

While completely in agreement with the view that the current set of circumstances has given rise to a situation in which there is a great deal of wasted effort and a burdensome amount of paperwork both for the investigator, the applicant, the institution, and the agencies of the Federal Government, I continue to believe that the project grant system offers greater advantages to the public, to science, and to the individual scientist than any other system yet devised. It assures that every project is subjected to individual scrutiny in peer review, and that it, on the basis of the best available scientific opinion, justifies its use of public funds. It allows the individual scientist to compete on the national level, free from the influences which may be operative at the local level which may have little to do with the true merit of the proposed project. It also assures that uniform criteria will be used in the selection of projects for possible funding. It provides for national recognition of the individual scientist - an absolute necessity in the career development of a mature scientist - in a way that funding from large grants in the local institution can never afford. Although the most recent figures are not available, Table 1 shows that the project grant has allowed the newly independent scientist to gain support at a rate that is quite gratifying.

Another concern that I feel about proposals to replace project grants with large center-type grants or with grants made on the basis of the reputations of well-known scientists, is that they will of necessity be made at a few existing large research institutions, and investigators at smaller, less well-known institutions will be placed at a great disadvantage in the competition for the very scarce funds now available or those likely to be available in the future. Another problem with large center-type grants is the institutional dependence on them which inevitably develops, particularly in those instances in which they have been in place for a number of years. If the funding agency finds it necessary, either because of limited appropriations or because the quality or productivity of the scientific work has declined, to curtail funding, very frequently major individual as well as institutional dislocations will occur.

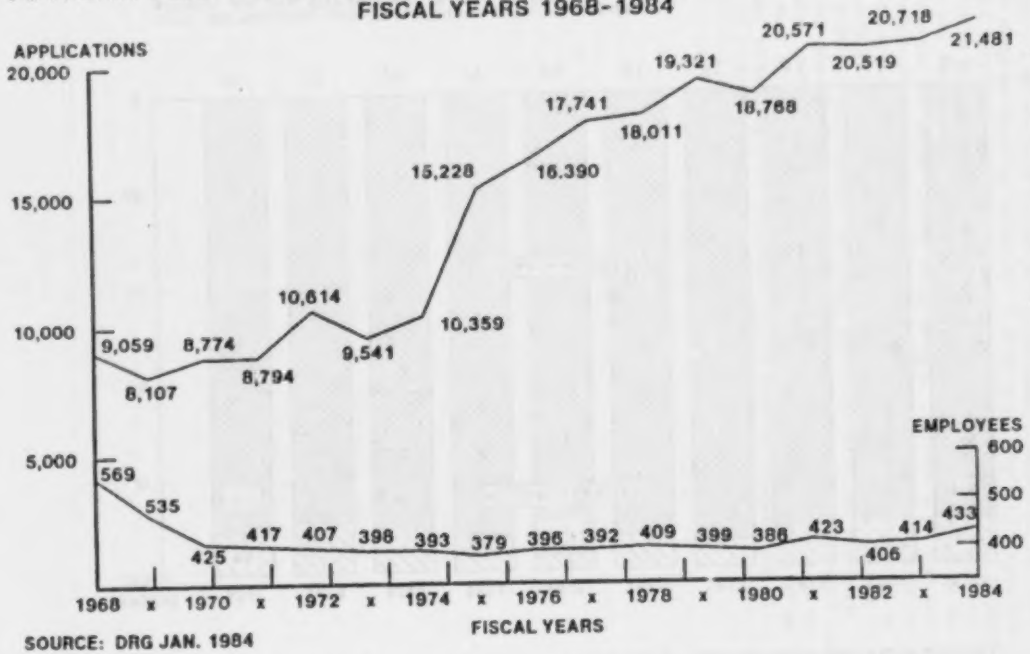
In summary, I think that the project grant should remain as the keystone of programs funding research. I also think that it is possible with hard work and understanding on the part of all concerned, to modify existing procedures in such a way as to simplify the application process and the processing of the applications by the agencies to decrease the current awful burden of paperwork. I think also that project periods could be lengthened, particularly for those projects of high scientific merit, in order to provide more funding stability to the investigator. I should emphasize that I do not oppose the use of center grants in appropriate settings, but I do not think that such mechanisms should displace project grants as the principal support instrument. It is also my firm conviction that the substitution of any system that eliminates competition and substitutes some.system of entitlement to funding will seriously injure American science and will result in a large wastage of taxpayer dollars.

DISTRIBUTION OF NIH COMPETING RESEARCH PROJECT, RESEARCH CENTER, AND OTHER RESEARCH GRANTS, FISCAL YEARS 1976–1985 (CURRENT DOLLARS IN MILLIONS)



NOTE: SEE TECHNICAL NOTE ON PAGE III FOR ACTIVITY COVERAGE.
SOURCE: NIH, DRG, STATISTICS AND ANALYSIS BRANCH

Figure 1

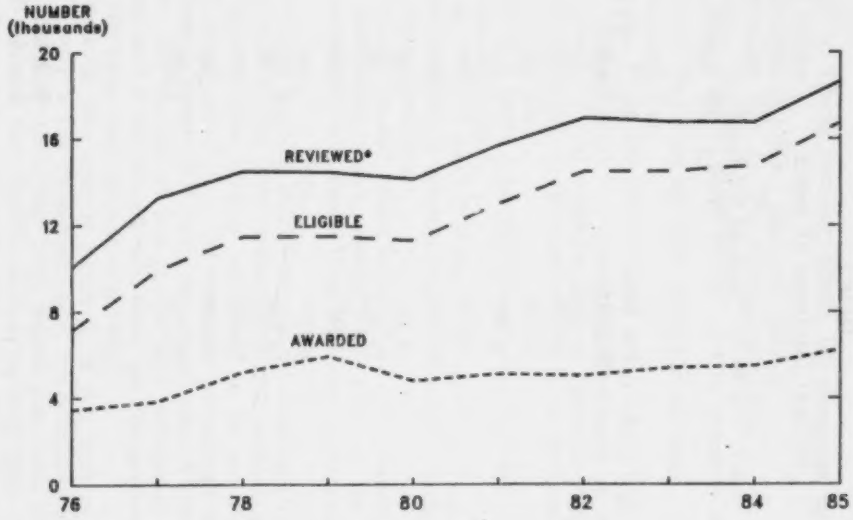


DIVISION OF RESEARCH GRANTS
TOTAL APPLICATIONS REVIEWED AND TOTAL NUMBER OF EMPLOYEES
FISCAL YEARS 1968-1984

SOURCE: DRG JAN. 1984

Figure 2

NUMBER OF NIH COMPETING RESEARCH PROJECT APPLICATIONS REVIEWED, ELIGIBLE AND AWARDED, FISCAL YEARS 1975–1984



NOTE: EXCLUDES TQ. SEE TECHNICAL NOTE ON PAGE III FOR ACTIVITY COVERAGE AND PROCEDURES.
*REPORTING YEAR.
SOURCE: NIH, DRG, STATISTICS AND ANALYSIS BRANCH

Figure 3

Table 1

National Institutes of Health

New P.I.'s on All Types of R01 Grants Compared to Number of P.I.' on All Types of R01 Grants

Fiscal Year	All R01 Awardees	New P.I.'s Number	New P.I.'s Percent
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RAEB/DRG
July 5, 1983

DISCUSSION

Mr. **Fuqua**. Thank you very much, Dr. Douglass, and a very interesting review.

I'm interested in table 1 that you showed.

Dr. **Douglass**. Yes, sir. The new investigators.

Mr. **Fuqua**. The new investigators.

Dr. **Douglass**. Yes, sir.

Mr. **Fuqua**. That that has gone down almost half.

Dr. **Douglass**. Yes.

Mr. **Fuqua**. From the 1974-75 era, which was a high year, but it remained above, almost 11 percent, and then back up to 15 in 1979. I notice, though, if you compare that on figure 2, that that was a time of rapid increase in the applications to be reviewed.

Dr. **Douglass**. Right.

Mr. **Fuqua**. Is there a correlation between the two?

Dr. **Douglass**. Indeed.

Mr. **Fuqua**. And I don't find one that has—that I can put together, that has a spending curve going up. Was there a rapid spending increase during that time?

Dr. **Douglass**. Indeed, there were—if we may convert that spending rate into, shall I say, award rate—that is, the number of projects awarded—that was a time when we were awarding more projects.

We have been keeping track—excuse me—we kept track, when I was at the NIH of this factor from about 1966 on through 1982 that you see here—I hope they've continued to do so—and we found almost an exact correlation between the percentage of new folks getting funding every year with our award rate. If the award rate went down, the number of new people as a percentage of the total went down, and if the award rate went up, the percentage of new people of the total went up just in parallel.

Mr. **Fuqua**. If you look at figure 2, if you look at starting at about 1979, with a few little hiccoughs, it's relatively a stable line, going out through 1984, but 1982, where you have the last—I'm looking at figure 2, but I'm also comparing it to table 1. It's rather stable in the number of applications. Now how was the funding during that time?

Dr. **Douglass**. I don't have the exact figures with me, but it varied, and I believe I can recall that funding was fairly good in 1979 and 1980 but had begun to diminish, as expressed in the award rate, through 1981 and 1982.

Mr. **Fuqua**. Now do you have any data to compare to the number of new investigators supported by other funding mechanisms?

Dr. **Douglass**. No, sir, I don't; it has been the project grants—what we in the vernacular call the RO1's at NIH—which we have focused on in those studies. Obviously, the new investigator-type grants that the NIH awards are all made to new investigators.

Mr. **Fuqua**. Did you keep track of where the new investigators came from? Were they from the older established institutions, or they were some of the newer institutions?

Dr. **Douglass**. We were not able to either afford or to collect the data to do complete studies of that sort, although we wanted to, Mr. Chairman. So such data are not available.

Mr. **Fuqua**. There have been some who have indicated that there is such intense competition for project grants that they've had the tendency over the years to judge the faculty member less on the research results but more on how much grant money he brought in. Is this a healthy trend? Is that what is happening? And is there something we need to do about it if it's bad?

Dr. **Douglass**. I certainly agree that it's not a healthy trend but that it is happening, indeed. I'm not sure that there's anything that I could have seen to do about it, working in a Federal agency. It's a matter of the institutions—the universities and the other research institutions in the country—having their priorities established so that other criteria which are important in their own programs—teaching ability, other things that the university might consider important—are considered in selecting and advancing faculty members.

Mr. **Fuqua**. Do you see that as a continuing trend?

Dr. **Douglass**. As things get tighter, I don't think it's going to diminish; right.

Mr. **Fuqua**. That was the point. As the resources for basic research become more and more stable, or stable and more constant, there's going to be more competition for that same amount of money, and it seems to be that there is a trend that you're judged by how much money you bring in rather than the quality of your work.

Dr. **Douglass**. It's unfortunate.

Mr. **Fuqua**. Does the peer review system make adjustments for that?

Dr. **Douglass**. The peer review system, as it operates at the NIH, does not. It is bound to judge the merit of the applications before it—the proposals before it, on the basis of established criteria for judging merit, and I don't know of any way that it could intrude itself into the local situation in such a way as to encourage or discourage the universities from doing this.

Mr. **Fuqua**. It's been suggested over the course of the hearings that we've had on this Science Policy Task Force, by some others, that maybe there should be a criteria that—suppose someone went to NIH, and you said, "We are not really interested in what you're planning on doing; we're interested in what your track record—what have you done in the past?—and we'll grant you *x* dollars; we're not really concerned about the specifics of your proposal." How would that readjust the system to try to look for meritorious science?

Dr. **Douglass**. I think some of that is already operative, Mr. Chairman, particularly as the peer review system looks at requests for continuation. I think that is really the preeminent criterion currently in use, even though it probably isn't as explicit as it ought to be.

Mr. **Fuqua**. Well, you are supposed to be, in the peer review, judging it on the scientific merits——

Dr. **Douglass**. Right.

Mr. **Fuqua** [continuing]. Rather than how many grants that you've had in the past.

Dr. **Douglass**. Indeed. Right.

But if by "in the past" we mean the productivity, the demonstrated good work that's been done, I think it is used, and probably if it were used more, or more explicitly, would probably be a healthy thing, indeed, and would diminish a lot of unnecessary redtape in the review.

Mr. **Fuqua**. I notice that the number of employees in the Division of Research Grants has decreased over the past 10 to 15 years.

Dr. **Douglass**. Yes.

Mr. **Fuqua**. And the number of applications has more than doubled during that period of time. How do you adjust the review process to take care of this dramatic increase with less people?

Dr. **Douglass**. With difficulty. We have had to increase the productivity of each of those individuals by several orders of magnitude. We have had to put in all of the automated devices and computer-assisted processes that we could. We have—as far as the employees are concerned, we have worked folks very hard, and we have demanded performance and assisted them with labor-saving devices to the extent that we could.

We have, I might add also, increased just as much the work on the people who are doing the reviewing from the outside, the peer reviewers from the non-Federal sector, and we have demanded and received a great deal more work, and effort, and productivity from them as well in this period.

Mr. **Fuqua**. Mr. Lujan.

Mr. **Lujan**. Thank you, Mr. Chairman.

It's very commendable that about 10 percent of the new grants are new ones, and I think that keeps—but I do notice that it keeps going down.

Dr. **Douglass**. Right.

Mr. **Lujan**. From 14, 10, 9, 9, 8. Is there a particular reason?

Dr. **Douglass**. It's again that funding rate. If you got that funding rate up, the new investigator as a proportion of the total would become larger.

In other words, when you increase the overall competition for the dollar in a particular year, you disproportionately influence negatively the ability of the new investigator to get some of those dollars.

Mr. **Lujan**. Because if you've got plenty of money, you're going to take a flyer at something.

Dr. **Douglass**. That's right. He'll have a better chance in the total competition.

Mr. **Lujan**. I don't see any table in some of our other reviews. NSF, for example, the top 20 get 50 percent of the funding. Do you have any kind of a table like that?

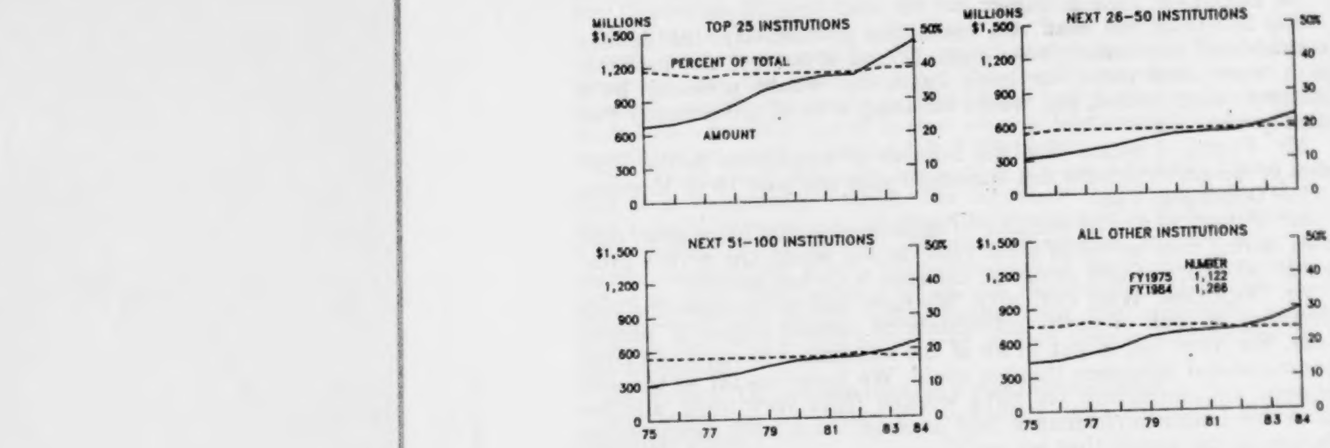
Dr. **Douglass**. It just so happens I do. May I pass it to you?

Mr. **Lujan**. Yes, it might be good to make some copies of it and keep it for——

Dr. **Douglass**. Sure.

[The table follows:]

NIH EXTRAMURAL AWARDS BY INSTITUTION RANK, FISCAL YEARS 1975-1984
(CURRENT DOLLARS)



NOTE: EXCLUDES TQ. SEE TECHNICAL NOTE ON PAGE III FOR ACTIVITY COVERAGE.
SOURCE: NIH, DRG, STATISTICS AND ANALYSIS BRANCH

Dr. Douglass. This table or chart shows that the NIH, overall, does business with about 1,300 to 1,400 institutions who do research. Over the years, the top 25 of those 1,400 have garnered in the competition about 40 percent of the dollars each year, and that has been just as level and steady since the mid-1960's. Although the total dollars has changed, the proportion of dollars has remained constant at about 40 percent.

The next 25 get about 20 percent of those dollars. I believe the next 50 get about 20 percent, and everybody else—the remainder of the 1,400—garner about 20 percent. That is, I think, a consequence of the way that the Nation's institutions concentrate on biomedical research. Since we were at the NIH a mission agency, we had to go where the biomedical research was, and that's the consequence of that.

Mr. Lujan. Do the people doing the peer review change?

Dr. Douglass. Yes; there's a regular rotation off the groups.

Mr. Lujan. Is it by design or——

Dr. Douglass. By design, absolutely. There's a fixed term so that in each group approximately one-third or one-fourth are rotating off each year and one-third or one-fourth are new people coming on. There are constraints on the reappointment of people to peer review groups; there has to be a lapse of time before you can have another period of service; other safeguards and restraints on the system to avoid getting an old boys' club which perpetuates itself; yes.

Mr. Lujan. Our task in this task force of course is, how do we improve policies—how we're doing it. As I went through your testimony and listened to you, the concentration of project grants versus institutional grants is a good one as far as you're concerned. The peer review system, without any interference from the outside; is that basically what that means?

Dr. **Douglass**. I've been associated with that peer review system throughout my entire career, and I assume you mean by "interference from the outside," is there a departure from adherence to those criteria for merit? I would say my experience is that, indeed, that's the case.

Mr. **Lujan**. And reduction of paperwork is one of the ones. How do we do that? We've been faced with that throughout Government.

Dr. **Douglass**. A number of things I would suggest. The first would be for the institutions, the applicant institutions themselves, to see if they can allay some of the desperation and panic in their ranks. There is a feeling among many investigators and many institutions that putting together a huge application improves their chances, and they do that, and it's unfortunate.

I think on the other side of that particular coin, the Federal agencies should adopt a strict size limit on the size of the applications, and enforce it, and say that you can only send in an application of no more than *x*—30 pages or something like this.

Mr. **Lujan**. Would it be advisable for us to do that?

Dr. **Douglass**. It would, in my view, certainly strengthen the hand of the agencies as well as encourage the institutions to diminish this.

Mr. **Lujan**. In the authorization you would say that we should say no application for grants should exceed 50 pages? Would that be helpful to you?

Dr. **Douglass**. I think it would be if, at the same time, you recognized that there are certain types of grants. The big center grants need to be bigger. If you're talking about project grants, I think a statement about the size of a project grant would indeed be helpful—project grant applications.

Mr. **Lujan**. And multi-year grants—you don't have those now?

Dr. **Douglass**. Yes. This is what that project period—period of committed support. The application is in competition 1 year, and if the award is made, it is for that year, the second year and the third year generally. It can go up to 7 by law, I believe, at the NIH, but traditionally it has been held very constant at about 3 years. Now if that were to be extended upward of 5 or 6 years in those applications that offer real promise, I think that would be a great help.

Mr. **Lujan**. Longer than 3 years?

Dr. **Douglass**. Yes. Let me——

Mr. **Lujan**. How would you have a review if you had—if you just make a grant for 6 years? Where would the review come in?

Dr. **Douglass**. It would come at the end of the 6 years, except for staff review. The peer review, though, would come in at the end of 6 years.

Mr. **Lujan**. If it's not going well, if the guy is just not doing anything, even under the 3-year grant now, does NIH have the authority, and do they just go in and say, "Well, you're not doing what you were supposed to be doing, and so we're going to cut you off"?

Dr. Douglass. It has the authority. It does indeed do staff reviews but not as any substitute for what is peer review; the staff would not do that; and, generally speaking, within the 3 years, it would be almost impossible to go out and say that with any confidence——

Mr. Lujan. And say, "You're not doing what you"——

Dr. Douglass. And say, "You're not"—yes. So it's generally been the policy to wait for that 3-year mark and then go for peer review.

Mr. Fuqua. If the gentleman would yield, isn't there some type of progress report that you make?

Dr. Douglass. Yes, indeed. There is a yearly progress report and a——

Mr. Fuqua. So if there was a problem developing——

Dr. Douglass. You would see it. The staff would see it.

Mr. Fuqua. You would see it before the end of the 3 years.

Dr. Douglass. Yes, yes.

Mr. Lujan. That's all I have, Mr. Chairman.

Dr. Douglass. May I say one other thing about this workload problem. If the Federal Government would reexamine its requirements—and I mean that very broadly; it's not just the particular agency, but across the Federal Government—if it would reexamine its requirements for assurances and reviews and so on, of administrative matters, I think a great deal of help could come from that quarter as well.

Mr. Lujan. How many of these are these big institutional grants that you shouldn't limit to 50 pages, percentagewise? Ten percent?

Dr. Douglass. Ten percent, roughly.

Mr. Lujan. Thank you, Mr. Chairman.

Mr. Fuqua. If you had a big, multi-disciplinary proposal involving several departments of a proposed project, it might be very comprehensive; you might be going after a very large grant.

Dr. Douglass. Indeed, indeed.

Mr. Fuqua. And it might require much more than that to justify it.

Dr. Douglass. Indeed. Yes.

I'm just talking about the discrete, one investigator, couple of technical help, a little bit of salary, and so on—the traditional RO1 grant.

Mr. Fuqua. Could not you limit that without Congress, if the word got out——

Dr. Douglass. Oh, yes. As a matter of fact, they are trying to do it right now.

Mr. Fuqua. Yes; we're not looking for a long—the quality of the report is not based on the volume.

Dr. Douglass. That's right.

Mr. Fuqua. I imagine that could discreetly cut down the size, if the word spread from the appropriate giving agency.

Dr. Douglass. Yes. Just last year they have begun to send them back when they were just outrageous.

Mr. Fuqua. In the GAO report, they talked about some of the funding mechanisms and suggested division of three broad categories of project grants, and program grants, and center grants, and within each of these categories, NIH, NASA, NSF, and other agencies have agreed to various kinds of different grants.

Since, in your testimony, you've talked about the retention of the project grants, do you have any recommendation with respect to several specific types of other grants that might be possible, such as the junior investigator grants, maybe travel grants, and maybe senior investigator grants, or maybe instrumentation grants to individuals, not with an earmarked set of funds?

At NIH this year we notice on table 1 that first-time investigators have gone down. We'd like to get that number up. Are we going to put aside some money and encourage those to come? Or we have some senior investigators that have been proven true over the years, that what they've produced has been outstanding, and all you have to do is just request some money, and we'll probably fund it for you, or some of the travel money or instrumentation money? What do you think about some of those approaches to this?

Dr. DOUGLASS. I think, if the agencies had that kind of flexibility where there wasn't—and which was not accompanied by a proliferation of formal, structured programs that have to be individually administered, and adding a lot of redtape in their own, I think that kind of flexibility would always be desirable, where the funds could be shifted to meet opportunities, where funds could be shifted to correct deficiencies in new investigators, or what-have-you—would be highly desirable.

Mr. FUQUA. I was not even suggesting a congressional set-aside but that within the agencies that the powers that be determine, we'd like to bring some more of these young investigators on board.

Mr. DOUGLASS. If that kind of decision could be given—decision authority could be given the agencies, it would be a great help; right.

Mr. FUQUA. I have a case of a relative of mine who goes to NIH for grants periodically, and he and a group of young—and he is young, getting younger all the time—but he and a group of young, very bright people submitted a proposal out to NIH, and they were turned down, and of course he was very disappointed, and I was inquiring, "Why were you turned down?" and he said, "Well, we didn't have enough experience," and he was saying, "You know, I don't know how we get experience if we can't"—here's a case of a junior investigator, at that time, and a group of them, his peers, that had made application for a rather broad type of grant, they thought very innovative.

But there are, I think, areas—and I don't cite this; it's just one that I happen to personally know about—where you can get experience.

Mr. DOUGLASS. Right. That's one of the strengths of the center-type grants at a local institution.

Of course, in that category of "other research" that you saw at the top of table—figure 2 there, there are a number of instrumentalities—research career development awards, the biomedical sciences research support grant, which is a kind of a large grant given to institutions which are engaged in research—which can be used to start young people or to give older people who are shifting fields interim support until they can get into competition and win their own support.

Mr. FUQUA. Well, Dr. Douglass, thank you very much for sharing with us this morning your thoughts, and it's been very interesting.

Certainly you come from a background of, I would say, being an expert in this field. We appreciate it very much.

Dr. DOUGLASS. Thank you, Mr. Chairman. It's a pleasure to be here.

Mr. FUQUA. Thank you.

[Whereupon, at 9:05 a.m., the task force was adjourned to reconvene on Thursday, March 20, 1986, at 8:30 a.m.]

RESEARCH FUNDING MECHANISMS

THURSDAY, MARCH 20, 1986

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to recess, at 8:20 p.m., in room 2325, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. Fuqua. Today we begin our last hearing on research funding mechanisms. We have been focusing on the GAO report. Today we are very fortunate to have Dr. Marvin Ebel, associate dean of the graduate school and professor of physics at the University of Wisconsin; and Dr. George Whitesides, department of chemistry at Harvard University.

We will begin this morning, and, Dr. Ebel, we will be glad to hear from you at the beginning. When both of you have presented your statements, then we will try to have some questions.

STATEMENT OF DR. MARVIN E. EBEL, ASSOCIATE DEAN OF THE GRADUATE SCHOOL AND PROFESSOR OF PHYSICS, UNIVERSITY OF WISCONSIN AT MADISON, MADISON, WI

Dr. Ebel. Thank you. Mr. Chairman, members of the Science Policy Task Force, my name is Marvin Ebel. I am professor of physics and associate dean of the graduate school of the University of Wisconsin, Madison. I would like to present some observations on funding mechanisms, which are based both upon my personal experience as a principal investigator, and also upon my activities and discussions as a research investigator. My comments will deal chiefly with the relative merits of block-type funding for research as opposed to single-project grants or contracts. I use the term "block-type funding" to encompass both the program and the center grants as described by the recent GAO report.

In general, I believe that the two GAO reports provide a sound introduction to the variety of mechanisms used, frequency of use of each, and the relative merits. My comments, therefore, should be regarded as amplification of the opinions expressed by the scientists quoted in the reports. I would also like to suggest some conclusions regarding funding strategies which I believe follow from the analysis.

Since I prepared my written statement, I have seen the statement which Dr. Pings made last week at one of these hearings. I support his comments. In fact, I am afraid I am going to reiterate some of them.

I have received research support both through a small-project grant, and also through program funding. In 1957, I became one of two principal investigators at the University of Wisconsin doing research in theoretical high-energy physics, supported by a contract from the Atomic Energy Commission; 6 years later, this contract was combined with a similar experimental high-energy physics contract at the university. By the time I had to withdraw from contract support in 1984, due to the pressure of administrative responsibilities, that contract had grown to include 18 faculty members—10 experimentalists and 8 theorists—comprising over one-third of the faculty of the physics department. Although not formally established as a center, its funding certainly carries many of the characteristics of program funding. This personal example, I think, illustrates an important point to be kept in mind when considering the adoption of particular funding mechanisms; namely, that funding for particular activities may evolve through time from the individual project to program or other block-type funding. Conversely, there are numerous recent examples where a center grant has been terminated and then replaced by a group of individual project grants. It stands as a corollary to this evolution of funding type that there exists a continuum of funding mechanisms, and precise categorization of the particular mechanism may not be possible.

Let me turn now to the advantages and disadvantages, as I perceive them, of block-type funding. The GAO report compares the merits of center grants versus individual project grants with respect to stability of financial and resource support, administrative burden, and the likelihood of introducing innovative high risk and interdisciplinary research. My own observations support the conclusions of that study that center grants do not reduce the administrative burden in preparing proposals, overseeing the grants, and in the general review process. It may be remarked that the possibility of this reduction in administrative burden is often suggested by faculty members as a principal reason for center or program grants. The truth seems to be that the proposals for center or program funding tend to be that much longer and more difficult to prepare than those for simple project grants.

The question of support for equipment acquisition has been discussed before you on several occasions in previous hearings, and I think I will not try to deal with that here.

However, there is little doubt in my mind that center grants do tend to provide a more stable source of support for the rest of the infrastructure which is so essential for progress in scientific research, if for no other reason than that the larger size of the awards make them much less likely to be terminated abruptly. Nevertheless, such terminations do occur, as I indicated previously; and when they do, the disruptions and dislocations can be severe. Recently, two centers at the University of Wisconsin, Madison, have had the block-type funding for their research activities terminated. In one case, approximately the same level of funding has been recovered through the mechanism of a series of individual project grants. It's highly likely that the same result will obtain for the other center. Nevertheless, the style of operation for each has had to change drastically. The obvious advantage of center or program funding is that it makes possible the sharing of support personnel, facilities, and equipment. These items are typically direct funded through the center, or program grant, or contract. When this funding disappears, alternative sources of support for the personnel and facilities must be found. In principle, such items could be funded as part of the indirect rather than the direct costs. In fact, that is the way these services are provided to investigators with small project grants. In practice, however, this conversion from direct to indirect costs is extremely difficult to bring about. For public institutions, State control of budgets may restrict or prevent adding these expenses even though subsequent reimbursement through the overhead rate might be possible. For all institutions, public and private, pressures to reduce rather than increase indirect costs make it unlikely that any appreciable fraction of this infrastructure can be transferred to indirect cost funding. The alternatives are to either direct-charge support personnel and equipment to individual grants or else to do without the equipment and require a highly paid researcher to devote time to routine laboratory tasks. In either case, there is a substantial loss of efficiency.

The conclusion is obvious, I think. Centers can provide more stability and efficiency in the funding of the infrastructure, but only to the extent that the center itself is stable. Absent this, it is more effective to fund individual projects and rely on indirect costs for the necessary sharing than it is to establish and subsequently terminate funding for a center.

A second advantage claimed for center funding is that, as the GAO survey indicates, scientists are more likely to perform innovative, high risk, or interdisciplinary research when working through a center rather than through individual project grants. I suggest that innovative research will be forthcoming only when the funding agency does not attempt to engage in micromanagement of the research center or program grant. Otherwise, the increased stakes involved in the large program, or center grant, or contract may dictate a very conservative approach to the selection of problems, picking that safe sort of research, unexciting sometimes, which will guarantee a respectable quantity of research output and hence assure the renewal of the grant. In other words, block-type funding can be a useful tool for encouraging research in new directions, but only when its potential advantages are not lost through overcontrol either by the university or the funding agency.

There is, I believe, one disadvantage to the center or program funding which is not addressed in the GAO reports. This is the problem of assuring and maintaining the highest quality among all those scientists supported by the block-type grant. Unfortunately—or perhaps it's fortunate—talents among scientists, as among all individuals in our society, differ. That's why we have peer review. Furthermore, talents and interests can change with time. Even though the original funding for the center or program may have supported only the very best of researchers, with the passage of time that may no longer be true. Such a change in ability or interest—and the change in interest may be the more significant—is very transparent in the single-project grant. It is more difficult to recognize and deal with in a program-type award, and it is still harder where the funding is for a center. There is nothing to prevent the peer review process for the center or program grant from focusing on the contributions of individuals rather than the center as a whole, but doing so creates the risk of stifling the innovative approach.

Here, as we have encountered previously, a sort of complementarity exists. The greater the detail of the scientific accountability, review, and management is required by the funding agency, the less likely the program or center is to move research in new directions. A balanced approach is called for, with full recognition of the costs of detailed management.

Finally, it's important to remember that in certain scientific areas program or center funding, rather than individual project grants appear to be essential. These are areas which are dominated by the need for the development of large instruments and facilities, where careful coordination of the research undertaken using these instruments is crucial. A prime example is, of course, experimental high-energy physics, although the increased sophistication of instrumentation in a variety of areas may bring them into the same mode.

Turning now to the stability of funding, regardless of the type of funding mechanism adopted, a key element for success is its stability. Researchers and institutions need to be able to make long-range plans for the optimum use of resources. The stability is simple to achieve with individual project grants by making awards for extended periods, from 3 to 5 years. While program grants could be made for such periods, and many center grants are now made for up to 5 years, the larger amount of funds involved may create difficulties—difficulties I am referring to for the funding agencies. This is especially true in situations such as we find ourselves in now, with large deficits forcing some sort of restrictive budgetary action. Where such extended funding at full level is not feasible, consideration should be given to either "shingling," whereby a decreased level of funding is assured for the long term, with prospective yearly increases, or else for long-term, core-grant funding of the center or program.

My specific recommendations are then as follows: first of all, although the individual project grants should remain the basic method of supporting research, program funding is appropriate and necessary in certain areas. However, care must be taken that these programs are subject to the same rigorous review given to individual project grants.

Second, program and center funding, as well as individual project grants, need to be for several years at a time to assure the necessary continuity in the infrastructure.

Third, a possible strategy for accomplishing both of the above goals is to fund a certain amount of core activities of a center and then to expect center members to also seek individual project funding for the bulk of their research. This can allow the agency more control over its long-term budget and at the same time provide for the crucial peer review necessary to assure the best research for the dollar expended. And I might add that this is a concept which I think Dr. Pings called "hybrid funding."

Finally, I would comment that centers can be useful to provide interdisciplinary research, but ideally they should be created in response to specific interests from the scientists themselves rather than as an overall attempt either by an agency or by a university to redirect the thrust of research. Thank you.

[The prepared statement of Dr. Ebel follows:]

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, D.C. 20515

SCIENCE POLICY TASK FORCE
TESTIMONY ON
RESEARCH FUNDING MECHANISMS

BY

Marvin E. Ebel
Professor of Physics and
Associate Dean of the Graduate School
University of Wisconsin-Madison

March 20, 1986

Mr. Chairman, and members of the Science Policy Task Force, my name is Marvin Ebel, and I am Professor of Physics and Associate Dean of the Graduate School of the University of Wisconsin, Madison. I would like to present some observations on funding mechanisms, which are based both upon my personal experience as a principal investigator, and also upon my activities and discussions as a research administrator. My comments will deal chiefly with the relative merits of block-type funding for research as opposed to single project grants or contracts. I use the term block-type funding to encompass both the program and the center grants as described by the recent General Accounting Office reports to this committee on University Funding.

In general, I believe that the two GAO reports "Federal Funding Mechanisms in Support of University Research" and "Assessing Federal Funding Mechanisms for University Research" provide a sound introduction to the variety of mechanisms used, the frequency of use of each, and their relative merits. My comments should be regarded as amplification of the main conclusions expressed by the scientists quoted in the reports. I would also like to suggest some conclusions regarding funding strategies which I believe follow from this analysis. I have received research support both through a small project grant, and also through program funding. In 1957, I became one of two principal investigators doing research in theoretical high energy physics, supported by a contract from the Atomic Energy Commission. Six years later, this contract was combined with a similar experimental high energy physics contract at the

University. By the time I had to withdraw from contract activity in 1984, due to the pressure of administrative activities which intruded too much on my research, that contract had grown to include 18 faculty members, 10 experimentalists and 8 theorists, comprising over one-third of the faculty of the physics department. Although not formally established as a center, its funding carries many of the characteristics of block type funding. This example illustrates an important point to be kept in mind in considering the adoption of particular funding mechanisms; namely, that funding for particular activities may evolve through time from the individual project to program or other block-type funding. Conversely, there are numerous recent examples where a center grant has been terminated and replaced by a group of individual project grants.It stands as a corollary to this evolution of funding type that there exists a continuum of funding mechanisms, and precise categorization of the particular mechanism may not be possible.

ADVANTAGES AND DISADVANTAGES OF BLOCK-TYPE FUNDING

The GAO report "Assessing Federal Funding Mechanisms for University Research" compares the merits of center grants versus individual project grants with respect to stability of financial and resource support, administrative burden, and the likelihood of introducing innovative, high-risk, and interdisciplinary research. My own observations support the conclusions of that study that center grants do not reduce the administrative burden in preparing proposals, overseeing the grants, and reviewing other proposals. It may be remarked that the possibility of a reduction in administrative burden is often suggested by faculty members as a reason for center or program grants. The truth seems to be that the proposals for center or program funding tend to be that much longer and more difficult to prepare than simple project grants.

There is little doubt in my mind that center grants do tend to provide a more stable source of support for the infrastructure which is so essential for progress in scientific research, if for no other reason than that the larger size of the awards make them less likely to be terminated abruptly. Nevertheless, such terminations do occur, as I indicated previously, and when they do, the disruptions and dislocations can be severe. Recently, two centers at the University of Wisconsin-Madison have had the block-type funding for their research activities terminated. In one case, approximately the same level of funding has been recovered through the mechanism of a series of individual project grants. It is highly likely that the same result will obtain for the other center. Nevertheless, the style of operation for each has had to change drastically. The obvious advantage of center or program funding is that it makes possible the sharing of support personnel, facilities and equipment. These items are typically direct-funded through the center or program grant or contract. When this funding disappears, alternative sources of support for the personnel and facilities must be found. In principle, such items could be funded as part of the indirect, rather than the direct costs; in fact that is the way they are provided to investigators with small project grants. In practice, this conversion is extremely difficult to perform. For public institutions, state control of budgets may restrict or prevent adding these expenses, even though subsequent reimbursement through the overhead rate might be possible. For all institutions, pressures to reduce, rather than increase, indirect costs make it unlikely that any appreciable fraction of this infrastructure can be transferred to indirect cost funding. The alternatives are then to either direct charge support personnel and equipment to individual grants, or else to do without the equipment and require a highly-paid researcher to devote time to routine laboratory tasks. In either case, there is a substantial loss of efficiency.

The conclusion is obvious: centers can provide more stability and efficiency in the funding of the infrastructure, but only to the extent that the center is continued. It is more effective to fund individual projects, and rely on indirect costs for the necessary sharing, than to establish and subsequently terminate funding for a center.

A second advantage claimed for center funding is that, as the GAO survey indicates, scientists are more likely to perform innovative, high-risk, or interdisciplinary research when working through a center rather than through individual project grants. I suggest that innovative research will be forthcoming only when the funding agency does not attempt to engage in micromanagement of the research center or program grant. Otherwise, the increased stakes involved in a large program or center grant or contract may dictate a very conservative approach to the selection of problems - picking that "safe" sort of research which will guarantee a respectable quantity of research output, and hence assure the renewal of the grant. In other words, block-type funding can be a useful tool for encouraging research in new directions, but only when its potential advantages are not lost through over-control, either by the university or the funding agency.

Interdisciplinary research raises slightly different issues. Here the key to success seems to be the degree of cooperation which goes on between individuals in different specialties. This in turn is a function more of the attitude of the scientists involved than the existence of a formal center. Center or program funding can make that cooperation easier, but they cannot force it to occur. The logical conclusion is that centers work best when they are a natural outgrowth of common interests, rather than dictated by university or federal directive.

There is, I believe, one disadvantage to the center or program funding which is not addressed in the GAO reports. This is the problem of assuring and maintaining the highest quality for all scientists supported by the block-type grant. Unfortunately (or perhaps fortunately) talents among scientists, as among all individuals in our society, differ. That is why we have peer review. Furthermore, talents and interests can change with time. Even though the original funding for the center or program may have supported only the very best of researchers, with the passage of time that may no longer be true. Such a change in ability or interest (and the latter may be more significant than the former), is very transparent in a single project grant. It is perhaps more difficult to recognize and deal with in a project type award, and is harder still where the funding is for a center. There is nothing to prevent the peer review process for the center or program grant from focussing on the contributions of individuals, rather than the center as a whole, but doing so creates the risk of stifling the innovative approach.

Here, as we have encountered previously, a sort of complementarity exists. The greater the detail of the scientific accountability, review and management, the less likely the program or center is to move research in new directions. A balanced approach is called for, with full recognition of the costs of detailed management.

Finally, it is important to remember that in certain scientific areas, program or center funding, rather than individual project grants, appear to be essential. These are areas which are dominated by the need for the development of large instruments and facilities, where careful coordination of the research undertaken is crucial. A prime example is of course experimental high energy physics, although the increased sophistication of instrumentation in a variety of areas may bring them into this mode.

STABILITY OF FUNDING

Regardless of the type of funding mechanism adopted, a key element for success is the stability of the funding. Researchers, and institutions, need to be able to make long-range plans for the optimum use of resources. This stability is simple to achieve with individual project grants by making the awards for extended periods, from three to five years. While program grants could be made for such periods, and many center grants are now for up to five years, the larger amount of funds involved may create difficulties. This is especially true in situations such as we find ourselves in now, with large deficits forcing some sort of restrictive action. Where such extended funding at full level is not feasible, consideration should be given to either "shingling", whereby a decreased level of funding is assured for the long-term, with prospective yearly increases, or else for long-term core-grant funding of the center or program.

RECOMMENDATIONS

My specific recommendations are as follows:

1. Although the individual project grants should remain the basic method of supporting research, program funding is appropriate and necessary in certain areas. Care must be taken that these programs are subject to the same rigorous review given to individual project grants.

2. Program and center funding, as well as individual project grants, need to be for several years at a time, to assure the necessary continuity in the infrastructure.

3. A possible strategy for accomplishing both of the above goals is to fund a certain amount of core activities of a center, and then to expect center members to also seek individual project funding for the bulk of their research. This can allow the agency more control over its long-term

budget, and at the same time provide for the crucial peer review necessary to assure the best research for the dollar expended.

4. Centers can be useful to provide interdisciplinary research, but ideally they should be created in response to specific interests from the scientists themselves, rather than as an overall attempt to redirect the thrust of research.

Mr. FUQUA. Thank you, sir.

Dr. Whitesides.

STATEMENT OF DR. GEORGE M. WHITESIDES, PROFESSOR OF CHEMISTRY, HARVARD UNIVERSITY, CAMBRIDGE, MA

Dr. WHITESIDES. Thank you. My name is George Whitesides. I am a professor of chemistry at Harvard University. My background as a consumer of Federal funds in research has touched on many of the mechanisms outlined in the GAO. I have dealt with a number of agencies through individual project grants. I have been a member of several block or program or center operations at one or another time.

What I would like to do, with the permission of you all, in the interest of saving a certain amount of time, is to submit the written testimony for the record and then touch primarily on the points in my summary and in my recommendations.

Mr. FUQUA. We will make it a part of the record.

Dr. WHITESIDES. Fine. I would like to make one or two general points and then touch on several of the subjects that seem to be of particular interest to this group.

First, I, as I think Dr. Ebel and Dr. Pings and many other people, strongly support the place of the individual investigator grant as the most efficient and most effective general method for supporting basic research, and the remarks that I make in what follows about special circumstances I would like not to be interpreted as some basic criticism of that fundamental place.

The second point that I would like to make which has also been touched on, is the critical importance of stability in basic research. Now, stability is a slightly touchy word in all of this. It doesn't necessarily imply that the duration of the grant is for a long period of time. It implies that the duration of support is stable. And it is possible, I would emphasize—and accomplished with many of the agencies—to have individual project grants that are renewed relatively often but still provide stability through the implicit contract between the agency and the investigator that continued good research will lead to some level of support.

So although I think it's very important to consider the basic idea of extending the period of support of individual project grants, it isn't an absolute necessity.

The third issue has to do with this matter of diversity. It is to me one of the great strengths of the American system that support in basic science comes from mission agencies, nonmission agencies, it's peer reviewed, it's nonpeer reviewed; it comes in a number of different processes. The great strength of this—the strengths—are two. One, is that this type of diversity permits the support of a very wide range of different types of science, a wider range than I think could be accomplished if one had a single unitary mechanism. The second, of course, is that it protects the scientific community from ideological shifts in the sense of the Mansfield amendment or related kinds of changes in Federal policy.

Now, with those general remarks, let me touch on what I think are a few subjects that deserve individual attention. The first is this matter that we have been discussing of the strengths and virtues of center or project grants.

In my opinion, the major reasons for using nonindividual investigator grants should be the solution of individual problems in funding of science. And the two problems which to me center grants are extremely effective at dealing with are: the support of infrastructure, and the stimulation or support of research that genuinely requires collaboration between investigators. I think the second point is obvious, and one has been touched on. The only point that I would make there is the general issue that one of the major functions that block or center grants have served in my particular career have been to produce what was often awful research—I mean just awful research—but wonderful education.

One of the great things that can happen in a block or center grant is that a group of investigators who are in some deep-seated sense fundamentally incompetent to work in a particular area of importance are brought together, they work in the area, and what comes out of it is a process of education which is almost, in my experience, unachievable by any other process. This is something which is a little difficult to quantify, but really very important and every effective.

Now, whether that process should go on for a very long period of time is an open issue. There is a great deal to be said for having one of these enterprises last for 5 years, at which point the individual investigators are well-trained, they know one another, and they can go off and do it by themselves in individual project mode.

The second issue is the support of infrastructure. This is a subject that, as someone who is involved in small science, I am particularly concerned with because large science has its own clear voices for the support of large instrumentation, but small science has had a great deal of trouble with this, and is having increasing trouble as the distinction between small and large becomes vaguer.

The institutions at which I have carried out research have used block or center grants very effectively to support shared instrumentation. Even with block or center grants, the instrumentation has always been severely and chronically underfunded, undercosted, and the operations have never run nearly as effectively as they should, and one of the strong arguments that I would make for a need to be solved in this area is some realistic—in an economic sense—mechanism for supporting instrumentation whose capital cost is in the few-hundred-thousand to few-million-dollar range. This is a very difficult problem right now to solve in universities, and I think the problem is becoming more serious as time goes on.

The last subject I would like to touch on is the matter of support of junior investigators—and I include in support of junior investigators the stimulation of graduate students, postdoctoral fellows, or perhaps even students even earlier on in their careers—to consider university basic science as a career.

The peer review system is a very effective method for supporting ongoing problems. It has a certain number of problems in providing funds, startup funds, for junior investigators.

Again, in all of the institutions in which I have worked, laboratories, projects, centers have been extremely effective in providing marginal support—that is, 20 or 30 or 40 percent of the total support for junior investigators—in a way which bypasses the peer review system at a time when the peer review system doesn't work very well. And I strongly support these kinds of funds which carry with them the opportunity for support of special projects such as junior investigators for those types of reasons.

Along with this, I would make an argument for programs such as the current National Science Foundation Young Presidential Investigator Program. The funds that go into that project are relatively modest. The great virtue of it is its, if you like, public relations value of convincing the young that the scientific community is making an active effort to support their beginning efforts and providing funds for that purpose. And it has been a very effective program at least in chemistry and materials science for giving the impression to promising students that their careers will be supported by the community.

So, in summary, I would argue for the support of the individual project grant, for recognition of the fact that the use of these different types of mechanisms of support is probably best to solve individual problems, and the individual problems are probably most clearly recognized by the individuals who are the lower level people in the individual agencies; that is, the ones in direct contact with proposals and in direct contact with the scientific community. An effort to manage this from on top carries with it certain problems.

We very much need improved mechanisms, of which one can think of several, to support infrastructure, long term, stable, recognizing the real life of the instrument and the real cost of this support. And none of the mechanisms, including center and project grants, presently do this. We need improved mechanisms for encouraging the young at the beginning of their careers and trying to make the perception of the university-based career in natural science an attractive one. I thank you.

[The prepared statement of Dr. Whitesides follows:]

March 20, 1986

Testimony on Mechanisms of Federal Funding for Basic Research

by

George M. Whitesides

before the Task Force on Science Policy
of the Committee on Science and Technology,
House of Representatives,
Honorable Don Fuqua, Chairman

Summary

1) **Individual project grants are the most effective method for supporting most university-based programs in basic science.** Stability is a critical parameter in this type of research, and the stability of individual project grants could be improved by longer grant periods, and by increased use of track record renewals.

2) **It is important to preserve the diversity in sources of support for research, and in styles of management within different agencies.** The availability to individual investigators of funds from non-mission and mission agencies relying both on peer review and on proposal evaluation not involving peer review makes it possible to support a very wide range of types of research activities in the United States.

3) **Multi-investigator program grants provide an effective method for supporting and stimulating research projects that require collaboration between multiple investigators.**

4) **Center grants also provide a method for stimulating collaborative or multi-disciplinary research.** The effectiveness of this stimulation would be greater if the size of the allocation to individual investigators were larger than is typically the case. Centers are also effective in providing shared facilities.

5) **The effective acquisition, maintenance, and operation of expensive shared facilities is an increasingly severe problem in university research.** Centers provide one method of supporting shared facilities, although the real costs of operating such facilities are often underestimated both by the center users and by the funding agencies.

6) Training grant and fellowship programs can provide a useful element of choice to individual students, and are a valuable alternative method for providing research support for junior faculty.

7) The generous support of junior investigators, both in reality and in appearance, is central to the health of the university research enterprise. Alternatives to individual project grants are particularly important for junior investigators.

March 20, 1986

Testimony on Mechanisms of Federal Funding for Basic Research

by

George M. Whitesides

before the Task Force on Science Policy
of the Committee on Science and Technology,
House of Representatives,
Honorable Don Fuqua, Chairman

Mr. Chairman and Members of the Committee:

Thank you for your invitation to appear before the Task Force on Science Policy. I appreciate the opportunity to provide my personal views on mechanisms of funding for scientific research in universities.

I am a professor of chemistry at Harvard University; before taking this position, I was a professor of chemistry at MIT. My experience with the federal funding of research has been primarily as an individual conducting basic research in universities in the areas of chemistry, biology, and materials science. Most of my research has been in "small" science; I have had only marginal contact with large instrumentation in national facilities.

My research at Harvard and MIT has been supported by individual project grants from several federal agencies including the National Science Foundation, the National Institutes of Health, the Army Office of Research, the Office of Naval Research, and the Defense Advanced Research Projects Agency. Additional support has come in the form of center or program grants from the National Science Foundation (as a member of Materials Research Centers at Harvard and MIT, and through the now-discontinued Research Applied to National Needs (RANN) program). I have also worked with doctoral and postdoctoral research students supported directly by training grants and independent fellowships (primarily from the National Institutes of Health). I have had direct contact with management of research grants programs in several of the federal agencies as a member of advisory groups (the advisory panel for chemistry for NSF, a study section for NIH, the advisory panel for chemistry for ONR, the Materials Research Council of DARPA).

I emphasize that my evaluation of the characteristics of the mechanisms for federal funding of research with which I have had experience is highly subjective. My remarks are based on my own personal experience, and on accounts of the experience of colleagues and associates.

The purpose of my remarks: I would like to:

i) Outline my perception of the strengths and weaknesses of several mechanisms for federal support of basic research: individual-investigator project grants, multi-investigator program grants, center grants, training grants and fellowship programs.

ii) Note several current problems in the management of basic research in universities that might, in principle, be addressed in part through adjustments in the balance of these funding mechanisms: support of infrastructure and shared facilities, assistance to junior investigators, and perception of the attractiveness of university research as a career by graduate students and postdoctoral fellows.

iii) Make several summary recommendations concerning these mechanisms of funding.

General Remarks.

First, I wish to emphasize my opinion that the peer-reviewed individual-investigator project grant is the most broadly applicable and generally effective method for providing the financial resources, the individual freedom, and the quality control required to conduct good basic research. In my following remarks, I will suggest certain circumstances in which this type of support of research may not be the most efficient or effective, but I do not wish these comments to be taken as a fundamental criticism of the individual project grant. I believe that the question is one of the proper balance between a majority of federal support based on individual project grants, and a minority of support based on other mechanisms of funding to deal with specific problems (e.g., certain types of interdisciplinary and engineering resarch, support of shared facilities, support of junior investigators).

Second, I emphasize the importance of stability in support in the conduct of basic research in universities. I believe that funding mechanisms that provide sustained, reliable support produce much higher quality science than support that is interrupted or uncertain, even if larger in dollar volume.

Third, I offer the opinion that one of the great strengths of the American system for federal support of research is its diversity. We enjoy a range of types of support, and of styles of management of this support. This diversity in types of support makes it possible for individual investigators and groups of investigators to find, howbeit often with some effort, a sponsor for a very large range of different types of research projects.

Having stated these general opinions, I turn to a brief, personal summary of my opinions concerning the different mechanisms for federal support of research.

Individual-Investigator Project Grants. The individual-investigator project grant remains, in my opinion, the most efficient method for supporting small and medium-sized research efforts in the university, in areas of science and engineering that do not require extensive collaboration or use of shared facilities. This mechanism offers the individual research scientist or engineer the maximum freedom to choose projects and to modify these projects as they are being carried out to meet new observations, while maintaining clear responsibility and accountability for the program and its results. It is particularly useful for research carried out in areas that have a clear disciplinary identification, and in which peer review is effective. It is arguably not ideally effective for certain types of high-risk projects, especially those falling between disciplines, or as the sole mechanism for support of junior faculty.

As currently employed by most federal agencies, the duration of individual project grants is approximately three years between competing renewals. For established, productive programs the uncertainties imposed by frequent competitive renewal, and the time spent on the renewal proposals, is at best an annoyance and at worst a significant impediment to the progress of the research. Some fraction of individual project grants would benefit from significantly longer intervals between competitive renewals. Experiments along these lines are underway (notably at NIH) and deserve encouragement.

I have mentioned the diversity of mechanisms of support as a strength of the American system. Let me illustrate my point with brief descriptive remarks on differences in management style in agencies with which I have had direct contact in my research in chemistry. The NSF is the most important source of support for core basic research in chemistry. It relies heavily on mail peer review, by a process that ensures high scholarly quality. Support from NSF is considered by chemists to be quite stable, although the duration of individual grants is short (in the past, 2-3 years) and the average grant size is relatively small. The peer review system is intrinsically conservative: it is excellent in discriminating against mediocre research, but sometimes slow to recognize very new areas.

The **National Institutes of Health** provides the major source of support for those parts of chemistry pertinent to biology and health. The NIH uses a panel form of peer review, and awards larger grants with longer durations.

The basic research agencies of the **Department of Defense** (**ONR, AROD, AFOSR**) use both peer review and internal review processes. These agencies have traditionally supported research having a more interdisciplinary character, and they have proved a particularly good source of support for exploratory projects in unconventional areas in many branches of chemistry and materials science.

DARPA works with relatively large grant sizes, but with grants of clearly limited duration. Grants are reviewed internally. Support of basic research by DARPA is relatively minor among its activities, and the basic science and engineering supported by DARPA is that regarded as having high relevance to particular DoD missions. This research need have no clear identification with any established academic discipline, and DARPA often encourages and supports unconventional research.

I have had no personal experience with the Department of Energy, NASA, or other agencies that support university research.

The point I wish to make from this recitation is that the individual investigator has the option to pursue research support that ranges in character from stable, disciplinary, conservative and peer-reviewed to interdisciplinary, unstable, unconventional and non-peer reviewed. Within this range, it is usually possible to find a sponsor for any sound idea.

Program Project Grants. Multi-investigator program projects provide a particularly effective method for supporting and stimulating collaborative and interdisciplinary research. The management of program projects is usually more complicated than individual project grants. They often start well, but it may be difficult to maintain a high level of quality for a long time. They are most effective when the amount of support going to each of the participating investigators is significant: high levels of support are most effective in inducing a commitment to the program effort by the individual participants.

Center Grants. Centers have a number of strengths: When they work properly, they stimulate interdisciplinary and collaborative research. They provide stable support for shared facilities and major instrumentation. They may have discretionary funds that can be used for special projects or to assist junior investigators in start-up. They have several disadvantages. First, if loosely managed, they do not stimulate collaborative work. Second, they can permit the continuation of research programs whose quality would be considered marginal as peer reviewed individual project grants. Third, inevitable pressures to distribute available funds over the largest possible number of investigators may result in levels of support too low to be efficient. In my opinion, center grants are typically not the best mechanism for providing support for the individual investigator initiated projects that constitute most of university research, and should not be used as a substitute for individual project grants. For the special but important cases of collaborative, interdisciplinary and engineering development projects, and of shared facilities, center grants provide a very effective mechanism for funding.

Training Grants and Fellowship Programs. Both training grants and fellowship programs differ from the mechanisms of funding discussed previously in that the funds go directly or indirectly to the students, rather than flowing to the students through faculty research directors. Portable fellowship programs probably give individual students the greatest practical freedom in their career choices: with independent financial support, they can choose institution, research area, and research group(s) without consideration of financial constraints. Training grants funded on the basis of peer-reviewed proposals provide an administratively simple mechanism for supporting research, especially in areas in which the major costs of research are in salaries. They have the additional attraction of providing a method under local control that can be used to assist junior investigators during start-up.

Each of these procedures for distributing research support has specific uses. The proper balance between them depends upon the character of the research being pursued. It is perhaps easiest to see the specific application of each, and to recognize ways in which each might be improved, by considering a series of objectives for research support.

Stability in Support of Basic Research. Basic research in universities is an enterprise that usually proceeds over a period of many years: A problem in basic research may require 5-10 years to proceed from initiation to full demonstration. Stability during this interval is critical to the smooth management of the project. Once a project has been carefully reviewed, and its basic principles have been demonstrated to be workable, uncertainties in funding, fluctuations in level in funding, and interruptions in funding are all destructive. Individual project grants are, in my opinion, the most broadly applicable mechanism for funding university research. They are not, however, the most stable as currently practiced. Grant durations of 2-3 years, with competitive renewal proposals required after only 1-2 years, are intrinsically unstable, administratively time-consuming, and emotionally trying for the principal investigator. The problem of instability is an inconvenience for a senior investigator, primarily due to difficulties in making commitments to graduate students and postdoctoral fellows that may extend over periods longer than the lifetime of the grant. This instability is a more serious problem for junior faculty, to whose research and career the premature termination or reduction of a grant may cause severe harm. The individual project grant system could probably be improved generally throughout the federal system if the duration of grants for established projects were increased from 2-3 years to 5-7 years. Program and center grants are, in practice, more stable than individual project grants. The advantage of stability does not, however, always counterbalance the weaknesses of multi-investigator program and center grants: sometimes capricious local management, small grant sizes, and a risk to junior investigators of loosing the identity of their research efforts in large collaborative projects. In my opinion, program and center grants should be used primarily to support shared facilities and to support and stimulate collaborative research, rather than as a mechanism to increase the stability or support for individual projects.

Support of Shared Facilities. The purchase of a major piece of instrumentation, even in areas of small science, may cost from $0.2 million to greater than $1 million; the real annual cost of operation and maintenance of this type of instrument is usually approximately 20% of its capital cost. This level of expenditure is beyond the resources of most single investigator projects, and good mechanisms for supporting major instrumentation, especially shared instrumentation or other facilities, very much need to be developed. The best current method for support of shared facilities seems to be center grants. The NSF Materials Research Laboratories have, for example, been very successful in providing shared facilities for the universities in which they are situated. Although centers can do a good job in acquiring and maintaining and operating shared facilities, such facilities are, in most universities, chronically underfunded. As university-based research moves more heavily to areas requiring the purchase and operation of major instruments, it will be increasingly important to develop improved methods for allocating realistic levels of support for these facilities. Center grants seem to provide the best vehicle presently available for this type of infrastructure support. The development of instrument grants that would provide both funds for the purchase of the instrument and realistic, long-term support for its maintenance and operation might provide an alternative.

Stimulation of Interdisciplinary Research. Major opportunities exist for research at the boundaries between a number of disciplines. For example, biotechnology can be considered an activity equally dependent on molecular biology, microbiology, chemistry, and chemical engineering; the important emerging area devoted to the development of new electronic materials requires participation from physics, chemistry, and electronics. To carry out research effectively in certain problems in these areas, it is necessary to be able to assemble groups of investigators having quite different backgrounds, and to induce these investigators to focus significant effort on common problems. Two mechanisms are effective in stimulating this type of interdisciplinary activity. Multi-investigator program grants are one; center grants are the second. Both work best if the quantity of support received by each investigator is sufficient to catch and hold his/her attention. In practice, maintaining adequate levels of support for individual components in interdisciplinary projects seems to be more effective in program grants than in center grants.

Initial Support for Junior Investigators. It is critically important to the health of research in the United States to give junior investigators (that is, individuals just entering independent research positions) adequate or more than adequate support during the early stages of their career. Initial individual project grants are awarded to junior investigators on the basis of promise, since it is difficult to evaluate their independent performance early in their career. Individual investigator grants for junior investigators are usually too small to support their activities adequately. The distribution of funds from multi-investigator program and center grants under the management of local research scientists who know the junior faculty and their needs in detail provides an important and effective method for supplementing the initial research support for junior investigators. Fellowship and training grants provide another potential source of support for junior investigators that does not depend upon peer review.

Encouragement of Able Students to Enter University Careers in Research and Teaching. A current perception among graduate students and postdoctoral fellows is that obtaining financial support for research at the beginning of a university career is a discouragingly arduous process. The difficulty in obtaining start-up funds may in fact be exaggerated: a substantial number of sources of funds are available to those who are sufficiently entrepreneurial, and a number of agencies specifically target funds toward junior investigators. The peer review of individual project proposals from these individuals is also usually sympathetic. Nonetheless, the perception itself may deter good young scientists from entering university research careers. The availability of funds and student support from multi-investigator program, center, training, and fellowship programs is very helpful in making the initial stages of independent research less painful than it would be if the junior investigator were required to obtain all of his or her funds through single investigator projects. Specialized starter grant programs are also helpful, especially if their existence is well publicized. The young presidential investigator program, administrated by NSF, has been very useful in providing a highly visible source of support for outstanding junior investigators that does not require them to compete with established research groups for individual project grants, and that provides unrestricted funds for exploratory research.

Recommendations

1) Maintain the central role of individual project grants in federal support of university research in science. Improve the stability of these grants and decrease the administrative burden entailed in maintaining them by encouraging longer grant periods (5-7 years for established investigators; 5

years for junior investigators) and limited renewal for senior investigators on the basis of short track record proposals.

2) **Preserve the diversity in sources of federal support and in styles of grant management.** The mixture of support from non-mission and mission agencies, and of peer reviewed and non-peer reviewed proposal evaluation, permits support of a much wider range of types of research than would be supported by any single agency or style of proposal evaluation.

3) **Develop improved mechanisms for providing shared facilities** (major instruments, shops, animal facilities) **and for supporting the operation of these shared facilities.** In particular, encourage adequate staffing of these facilities with appropriate technical support staff.

4) **Encourage multi-investigator program and center grants as a method of stimulating collaboration in fields where appropriate.** These types of funding mechanisms stimulate collaboration and interdisciplinary work, provide shared facilities, and help to support junior faculty. Do not expect program and center support to substitute for individual project grants.

5) **Encourage the development of methods for supporting junior investigators that do not rely only on individual project grants.**

I thank you for allowing me to present my views on these matters.

DISCUSSION

Mr. **Fuqua**. Thank you very much.

You know, from reading your testimony it appears that everything is fine.

Dr. **Whitesides**. Not quite.

Mr. **Fuqua**. Well, that is what I would like to try to find out. Assuming we had 5-year funding, ample funding over a 5-year period, how could we make basic research or support research better?

Dr. **Whitesides**. Let me start to answer that question. I am sure Dr. Ebel will have his own opinions on this.

I think one major problem is the problem of infrastructure. And in my opinion, what may have to be done on that, given the real constraints and the total number of dollars that is available, is in fact to shift funds from these alternative mechanisms specifically into the support of instrumentation and facilities. I think that the scientific community in general is going to have to face the fact that if we wish to have more expensive facilities and more expensive instrumentation, and if we wish to keep these things up, we're going to have to pay for it.

Now, in order to pay for these, I am not sure that the unrestricted center grant is necessarily the most effective procedure, because the money goes into the center, the money is then redistributed according to local management. And the one difficulty with that is that there is a very strong tendency to take center money and redistribute it in such a fashion that it covers the maximum number of individual investigators with the minimum possible number of dollars, and that isn't always a procedure that leads to adequate support of these uninteresting subjects such as technicians for instruments.

Mr. **Fuqua**. But I think we all recognize the problem of infrastructure, and I think the members of the committee recognize that. But still, if we solve that problem, how can we make our funding mechanisms or our production of basic research in our colleges and universities better?

Dr. **Whitesides**. All right. Two other points which I would make. One is—and this is a very personal opinion—I believe that many of the opportunities which are most interesting in science and technology at the moment lie at the interfaces between established fields. And educational mechanisms, mechanisms that bring together investigators, are an important thing to try to stimulate. It's a place where Washington can actually do something.

Mr. **Fuqua**. You mean in the interdisciplinary area?

Dr. **Whitesides**. Multidisciplinary, biotechnology being an outstanding example, materials science being another outstanding example.

Mr. **Fuqua**. Where you bring chemists, biologists, and a lot of other people together.

Dr. **Whitesides**. Precisely.

Now, one of the difficulties with these kinds of areas is that they really don't work in a peer review system.

Biotechnology is now a sufficiently established subject that perhaps it must——

Mr. **Fuqua**. Then how do we make it work?

Dr. **Whitesides**. I think the way you make it work is to provide funds in sufficient quantity to catch people's attention for a sufficient period of time that they learn something sufficiently targeted for interdisciplinary research. And that means programs well advertised—and the advertising, I think, is a critical part of it—which make clear that there are opportunities for people to shift their field, provided they are willing to work with others and learn with others. And several of the agencies are beginning to try this experiment, but it's quite a recent kind of organizational effort, and I think it's really too early to say what the result will be. The response from the community that I work with has been quite enthusiastic to the general idea.

The second point I would touch on is just the issue of junior investigators because I think that is as critical a matter.

Let me let Dr. Ebel have his share of the say.

Mr. **Fuqua**. Dr. Ebel.

Dr. **Ebel**. Well, I think one of the things which I hear a lot in talking to faculty members at my university is that they are very worried about a trend in funding which they see, of a trend toward more center funding. And while they recognize the fact that it can be effective in the interdisciplinary areas, nevertheless, they fear this. Some of them, for example, have told me that: "Well, we're going to have to get together and propose a center because otherwise we're going to be shut out."

So I think one of the problems that I see is whether we can maintain our present system. I found the statistics in the GAO report very interesting in terms of the fraction of funding that was provided through single project grants, but I think the fear here, one of the fears, is the maintenance of that fraction.

Mr. **Fuqua**. Well, if you're talking about in the center grant program or core funding—I assume we're talking about that.

Dr. **Ebel**. Yes; yes, that's right.

Mr. **Fuqua**. How do you select the institutions to receive the funding, or do we then do it on the basis of how many other grants you have received?

Dr. **Ebel**. No; I think one of the mechanisms which I would propose would be in fact perhaps the mechanisms which are used for many of the centers now; namely, competitive proposals for it. The only difference from what I think we see happening is that the center funding would not provide the full funding for the activity.

Mr. **Fuqua**. It would be made up by local or——

Dr. **Ebel**. Would provide essentially infrastructure funding and then ask the individuals who are members of that center to still go out through the project type approach. It seems to me this places less of a long-term burden on an agency, and I think we have to worry about that. I think the scientific community has to worry about that.

Mr. **Fuqua**. Does this lend itself to "the rich get richer"?

Dr. **Ebel**. Not necessarily. Not necessarily. It seems to me that if you aren't asking the center to bear the full costs of the research, then it may be possible to try to spread the centers out more. I think still they ought to be competitive. I have a lot of trouble with the noncompetitive sort of awarding.

Mr. **Fuqua**. Dr. Whitesides, do you want to comment?

Dr. **Whitesides**. I would agree entirely that they should be competitive. And I think that the opportunity that one needs to provide is for groups of investigators who for whatever reason perceive an opportunity in collaborative research rather than a pot of money with which one tries to induce a group of investigators to carry out that research. That is, it has ultimately to be based on the interest of the individual investigators to conduct that sort of research.

And then above and beyond that point, whether it necessarily makes the rich richer, probably—in fact, I would argue the opposite because very successful senior investigators have a tendency to have their hands fully occupied with what they're doing. Often, one finds the best opportunity among beginners or in places which are perhaps a little bit to the side where there is a strong advantage to that group to try to put together something new.

Mr. **Fuqua**. Let's talk about the junior investigator or young investigator program. Yesterday we had testimony that related to NIH over the last several years that the first-time investigator getting funded was down half of what it was in about 1974–1975–1976, somewhere in that time frame. It was running about 15 percent of the grants at that time. Now it's down to about 8 percent.

How do we attract these young people into research, and how do we sustain them until they have a reputation and gain the confidence of their peers to move on out? Both of you are very well known, and at some point you had to start. We all had to start. How do you accomplish that—because I think this is a very real point, and you touched on it and I am very glad you did.

What has really concerned me is how do you interest and keep the interest of this young person? Otherwise, they may see these great big barriers presented against him and there is no hope for them ever getting recognized or getting funded or some project that they feel like they would like to engage in.

Dr. **Whitesides**. Shall I start?

Dr. **Ebel**. Yes.

Dr. **Whitesides**. I think that with junior investigators one has to have protected funds that do not go through peer review—not all, but some—and there has to be some mechanism for providing funds through local management, because no one knows the junior investigators, the ones who are really going to work out well and who deserve support better than the people who are local.

The two points that I would make in this regard are that it's not just a problem of the first grant. In fact, I think many people would argue that the most severe problem for junior investigators comes at the end of year 2 or year 3. They've gotten their first grant on the basis of promise and sympathetic peer review. They come back in and they haven't gotten very much done in 2 years; their program is just starting. They get cut off at the ankles and that's the end.

The problem with that is not only is it extremely hard on the junior investigator, but it makes for real pressures on the beginners to be conservative in their choice of problems. They're pushed by that mechanism to try to find research that can be accomplished in 2 years from no start, and nothing interesting probably can be accomplished in 2 years from no start.

So that something that is needed, I believe, is protected funds, appropriately distributed—and this is, I think, the difficult issue—with real assurance that it's going to last at some level over the course of 5 or 6 years, which is the critical period for most people who are just starting.

Mr. **Fuqua**. Dr. Ebel.

Dr. **Ebel**. Well, I would agree that there has to be some sort of protected funding, and I think the PYI program and some of the NIH programs help to meet that need.

I think it's also interesting to note that there are areas—mathematics is one of them; I think that my own area of theoretical physics is another—where people might argue that the young investigators have an advantage in terms of the currency of their knowledge.

And I think the other mechanism which works—I have seen it work a number of times—is an association, a temporary association with a more senior investigator. I think you always worry about the independence, but I mean you have to worry about that independence anyway regardless of the funding questions.

So I think there are ways of assuring it, and I think mainly you have to be aware of the problem.

Mr. **Fuqua**. Mr. Packard.

Mr. **Packard**. Thank you, Mr. Chairman.

Let me ask a question that I asked at an earlier hearing because it has direct bearing upon the funding mechanism. To what extent does the quality of the project application, the quality of the grantsman, those that put together the application, have to do with the success of the application in terms of grant awards? Are there some that have greater skills in putting together different kinds of mechanisms to cater to that success ratio?

Dr. **Ebel**. Well, I don't think that there is any question that there are some people that seem to have the touch, just as there are people who can explain themselves better, for one thing. I know of faculty members who have, what I believe, and I think many of their colleagues in the field would believe, are good ideas, good quality, who do have difficulty in understanding what is necessary to try to persuade individuals, others, reviewers, of their quality.

I think these, though, tend to be exceptions rather than the rule. So I would say, in general, the two factors which do enter into the funding are the quality of the project and quality of the investigator. Now, there is a lot of discussion, of course, about trade-offs between those two items.

Mr. **Packard**. But generally speaking, you feel that the better research institutions or the better research projects tend to draw better grantsmen?

Dr. **Ebel**. Or better quality individuals. Yes, I think in general I would say that.

Mr. **Packard**. Does the nature of the research tend to dictate the mechanisms used for funding?

Dr. **Whitesides**. Yes; to a significant extent. That is, there are areas, if one is interested in biology or things that are related to health, of necessity you deal in major part with the National Science Foundation, the National Institutes of Health. They have a particular set of devices. If one is interested in materials or solid-state physics, there is a stronger tendency to work in the side of the Department of Defense, which has a very different set of mechanisms. So there is some distinction in that regard.

Mr. **Packard**. What about the nature of the research project; for example, would basic research tend to gravitate toward one kind of funding mechanism versus project-oriented research toward a different type of mechanism?

Dr. **Whitesides**. Certainly, basic research in most areas tends to gravitate toward individual project grants. The farther that one gets toward things that have, if you like, a research engineering character, the more likely it is, I think, to find involvement in project center grants.

Mr. **Packard**. Dr. Whitesides, you stated that the greatest strengths of the current system is in its diversity. In your judgment, do you believe that the current mix is serving the needs of our research as well as could be done, or are there some recommendations you would make in changing that mix of variety and the diversity of mechanisms?

Dr. **Whitesides**. I would recommend perhaps a shift. Again, let me emphasize my personal enthusiasm for interdisciplinary research. And for interdisciplinary research, I feel that stronger support in areas which permit individual investigators who wish to collaborate in collaborative research would help the science establishment in the United States. I think a shift of the same sort would also help junior investigators and would also help to deal with the infrastructure problem.

But I think that the amount of any shift should be relatively small. I do think our current system actually works pretty well and that what one needs to do is to provide a bit more support and opportunity in these problem areas.

Mr. **Packard**. Dr. Ebel, you also placed high priority on stability of funding, but you also argue strongly for the maintenance of the competitive nature of selecting grantees. Do you find these two criteria contradictory, and will research for both stability and competitiveness not tend to gravitate much of the funding toward larger institutions?

Dr. **Ebel**. Well, sure, in the extreme. I mean, clearly they are contradictory. And so what I am suggesting is a balance here between—which I think can best be achieved by either the long-term grant or, as Dr. Whitesides pointed out, the long-term understanding, if you will. But I think stability cannot be taken to mean static; in other words, you have to allow for some change. You have to recognize that projects which may at one time have been worthy of extensive funding may no longer be worthy of such funding.

I think the thing which many of us worry about are precipitous changes. Now the question of, "Does it mean the rich get richer?" I don't think so. I don't think so. And I think, if you like, the peer review system is maybe the greatest protection for that. I think that there are opportunities both for individuals who have good ideas to get good funding through the peer review system. I think there are opportunities also for institutions to build through the peer review system. I think, in effect, that really is one of the protections against the rich-get-richer.

Mr. PACKARD. One last question, Mr. Chairman, if I may.

As we move more and more toward private funding or funding of some kind of marriage between public and private funding mechanisms—or procedures, rather—does that tend to change the funding mechanism? Do you see where there would be a shifting of funding mechanisms as we get industry and the private sector more and more into helping and participating on the funding?

Dr. WHITESIDES. No; I would remark that I would have to see that to believe it. I understand the desirability of that. But the contact I have is with the chemicals and materials industries, and I see great reluctance to be heavily involved.

I think that that kind of involvement is very desirable for two purposes. One is helping to move basic research into the real world. It can be very good at that. It can be absolutely splendid if there is a collaborative element in helping in the educational process, both for junior and senior investigators, to bring them into contact with problems.

But it is necessarily going to be more short term, in general. It is necessarily going to be more along the lines of, if you like, a project grant; the project may involve people in the university or it may involve some collaboration between university and industrial researchers. But I think it will tend to strengthen the collaborative project part of the spectrum and, in fact, do almost nothing for the traditional peer-reviewed individual investigator grant.

Mr. PACKARD. Dr. Ebel.

Dr. EBEL. Yes; I think I would agree with that. I would just comment that in the engineering area one of the most common sources of private support is through the consortium type arrangement, which is by definition a center-type arrangement.

Mr. PACKARD. Thank you very much.

Thank you, Mr. Chairman.

Mr. FUQUA. Mr. Lujan.

Mr. LUJAN. Thank you, Mr. Chairman.

Dr. Whitesides, one of the comments you made was that continued good research will lead to other funding. Dr. Ebel says be careful of the overcontrol. So how do we know what continued good research is? Continued good research maybe would be if the universities came up with a vaccine for the common cold, why, you know, you'd be excellent. If we would be looking to you for other things, then the funding wouldn't flow. Is that what good research is?

Dr. WHITESIDES. I think good research has two aspects. One is good research cum research is something that passes the peer review system. That's the best protection we have for basic research in which it is sometimes difficult to see the results.

Mr. LUJAN. What if you are skeptical of the peer review system?

Dr. WHITESIDES. Then there is another mechanism, and that is that with the mission agencies, the mission agencies generally have some objective in mind and support through a mission agency suggests that someone in the mission agency can make a connection between the research that's being done and some objective.

This is precisely what I like about the diversity of the system. There is research that is viewed on the basis of intellectual interest within the peer part of things, and then there is another stratum which is actually very significant in terms of intellectual contributions, although not necessarily so significant in terms of dollars, in which the product is judged on the basis of its ability to be applied to some variety of practical problem. So I think both of these elements are built in at the moment.

Now, the further question of are there better ways of doing this or other methods of doing this, essentially come, I think, to the point that Mr. Packard raised: "Are there better arrangements that can be worked out which would move things more directly from the university into real applications in industry?" And we haven't been very good at working out those kinds of arrangements yet. The one place where you see it work spectacularly well has been in biotechnology, but that, of course, is a complicated special circumstance.

Mr. **LUJAN**. Does the Defense Department have a peer review system? When they want something that fits a particular application and they go out and contract with someone to do it, do they have this whole peer review system?

Dr. **WHITESIDES**. The Department of Defense has several different strata. Each of the agencies has a basic research agency, a 6.1 agency, which, depending upon the branch of the DOD, may use peer review or it may use internal review. Then there is an additional series of levels which go through development research and engineering research in which one moves much more strongly into pure internal review and contract mode.

But the DOD has the full spectrum of activities, in general, with increasing funds and decreasing durations of support as you go to more applied problems.

Mr. **LUJAN**. Through our national laboratories we have a kind of, I guess, an inverted system where their goal is application, primarily, and so you build up your big organization for the bigger bang or, you know, more accurate weapons or whatever you're going to do, but under that is all of this basic research. Even further beyond that, the laboratory directors have a discretionary fund so that if somebody gets a bright idea, let's follow it through.

In university research we have just the opposite, as I understand it, and that is, your basic research, and then if you have some particular application you go to the individual grant.

Dr. **WHITESIDES**. Right.

Mr. **LUJAN**. That would seem to speak for the idea of centers, that you have a basic research center from which the application of research—for lack of a better word—from which that will grow.

Dr. **WHITESIDES**. I think that that kind of mechanism can be very attractive. But even as someone who happens to be very interested in technology transfer and deeply supports those kinds of activities—I love engineering research—it is my belief that this basic research activity—that is, research in which it is very hard to identify specific products—is an enormously important and enormously valuable activity to protect. It's sometimes hard to justify, but I think that if you look at it carefully, you would find that anything that is developed has to depend upon that kind of thing.

Mr. **LUJAN**. I think we're saying the same thing.

Dr. **WHITESIDES**. All right. Well, maybe I misunderstood the point of your remarks.

Mr. Lujan. You have your center for your basic research out of which will flow these applications. If we were to follow that course, then, for example, as the health care system has through their health care agencies in each State, they try to control where you would go if you have a heart attack, some place is designated for that, or a burn trauma, whatever.

Is that not a good system for the basic research, to take one institution and designate that as the one responsible for a particular type of research and take another institution and do your basic research?

Dr. Whitesides. I am sure both Dr. Ebel and I will have remarks on that subject. My personal view is that science, as everything else, works on the basis of warm, understandable human emotions such as greed, avarice, sloth, things of this kind——

[Laughter.]

Mr. Lujan. Just like politics. [Laughter.]

Dr. Whitesides. Just like politics. And the great virtue of a system in which individual investigators do things is that they do it for their own purposes. Whenever one has a center, I think one has to ask, "Does the center really fit the individual objectives of the individual investigators?" And there are circumstances in which it does.

I mean, to take the example of burn, there is a whole spectrum of activity ranging all the way from extremely exciting epithelial cell culture, basic cell biology, all the way through very, very interesting problems in clinical medicine, and one can imagine putting together a group of investigators that would like to cover that entire spectrum and really having it work well. Here may be an opportunity for the involvement of money because people will sometimes work with the inconveniences of collaboration if there is enough money to make it worth their effort.

But I think to try to say there is going to be such a center, and then expect the proper coagulation of individuals to occur, it usually doesn't work.

Mr. Lujan. There is a certain prestige in saying, you know, "I run this burn center and I am one of the prominent investigators of that."

Dr. Whitesides. We folks in universities are unbelievably fractious, and prestige is fine but not if you have to put up with somebody telling you what to do. [Laughter.]

Mr. Lujan. Dr. Ebel.

Dr. Ebel. I agree completely with that comment. I think there is always the problem, which I tried to express, that interests change among faculty members, and one of the real difficulties of the center concept is that it seems to me that by its very size, it has difficulty responding to those changes of interest. I think without the interest, the research doesn't really go very far.

Mr. Lujan. One final question, and I guess it's a very basic question that I would like to understand. That is, what is our goal with university research? Is our goal primarily to educate new scientists coming along, or to get results out of the funding?

Dr. Ebel. I would say both. I think we're in a fortunate position that they aren't contradictory goals. I think that, in fact, it's very difficult to sort out when you're working with a graduate student whether you're learning more about the science or teaching the student more or he or she is teaching you more.

It's really such a complementary process that I think we've never really said university research is primarily for the achievement of results, of progress of knowledge, nor have we said that it is primarily for the education of students. It's really for both, and I think we're fortunate that that doesn't get us into trouble.

Mr. LUJAN. If we did do that, however, if we did say the goal of the university is to educate the people coming on, funding might be more stable because you're not expecting those results.

Dr. WHITESIDES. I think it's possible that you could say that the goal of the university is to educate both students and also, again let me emphasize, junior faculty because there is some commonality in that. But I think that you will never be able to avoid the fact that good education will produce good research. Of course, one doesn't want to, but the two are absolutely inextricable. What one is trying to train students to do and to encourage junior faculty to do is to do good research.

I think the only issue that I could argue about is what is the definition of the word "good" in that context. To what extent should one really protect research just for the sake of knowledge with the expectation that it will eventually help society in some more complicated way and to what extent is it appropriate to ask that question at the beginning?

Mr. LUJAN. We've come full circle. My first question to you was——

Dr. WHITESIDES. Exactly.

Mr. LUJAN [continuing]. What is good research?

Dr. WHITESIDES. That's exactly right.

Mr. LUJAN. Thank you very much.

Thank you, Mr. Chairman.

Mr. FUQUA. Thank you, Mr. Lujan.

Dr. Ebel, you in response to a question from Mr. Packard, I think, if I quote correctly, said that the peer review process didn't make the rich richer. There are a lot of my colleagues who disagree with that statement and there are a lot of university people who disagree with that statement. Could you elaborate?

Dr. EBEL. Yes; I guess I probably should have been a little more careful. I think that the one protection for a nonrich individual or institution is the peer review system. I think that's the opportunity which the individual, or the institution, has to move up.

Mr. FUQUA. But a lot of them think it's stacked against them.

Dr. EBEL. Well, I guess I simply have to disagree with that assessment. I happen to have had a number of students who have gone on to institutions which are not primarily research institutions and become faculty members there.

One of the things that I am very concerned about are the research proposals that they put in. I think that the notion that somehow there is a network which tries to hold down proposals from certain groups of faculty, or faculty from certain groups of institutions doesn't correspond at least with what I have observed in the peer review system.

Mr. FUQUA. Would you care to comment, Dr. Whitesides?

Dr. **Whitesides**. The only remark that I would make there, coming from a research university and accepting that as a prejudice, is that of course doing basic research is an activity which is sometimes done best in a circumstance in which one has a collection of, if one can, the best students, the best junior faculty, the best resources. It is an expensive and complicated operation.

And the question of how many of these really exist in a functioning sense in any field at any time is probably smaller than the total number of universities that are research universities. So that to the extent that one of the objects of university research is to produce research, I think that some concentration of resources is both inevitable and desirable.

Mr. **Fuqua**. Thank you, gentlemen, both very much for sharing your time with us this morning, and your thoughts. Thank you.

[Whereupon, at 9:31 a.m., the task force was adjourned to reconvene on Tuesday, April 8, 1986.]

[illegible]

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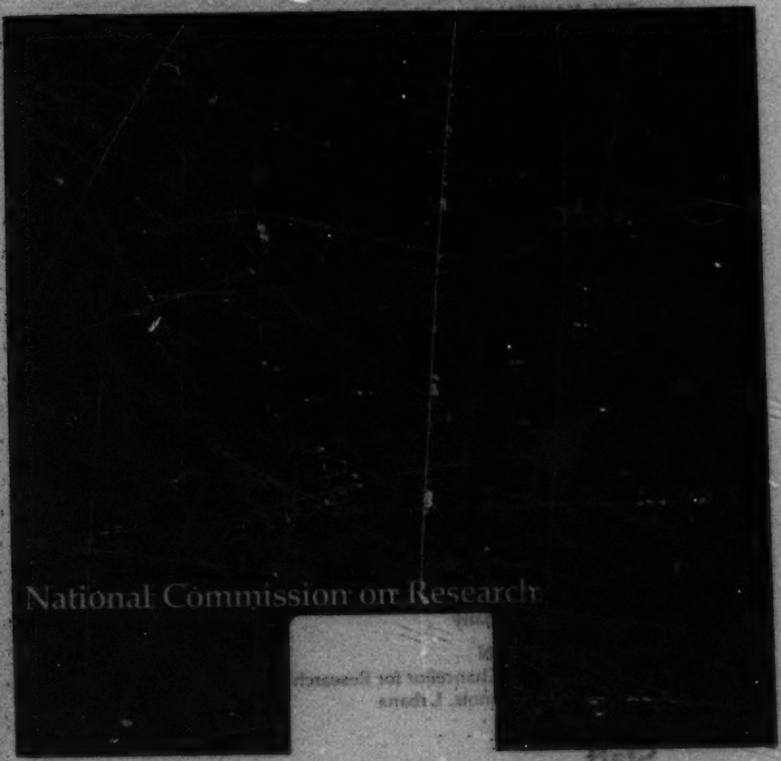
Mr. FUQUA. Would you care to comment, Dr. Whitesides?

APPENDIX

FUNDING MECHANISMS:

Balancing Objectives and Resources in University Research



National Commission on Research

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NATIONAL COMMISSION ON RESEARCH
Funding Mechanisms: Balancing Objectives and Resources in University Research

Executive Summary

For the better part of a half century, the Federal government and the research universities of the nation have been associated closely in the support and performance of research. Recently, this relationship has become strained. The partners have developed different views on the objectives of their association and the conditions of their collaboration.

The Commission

The National Commission on Research was formed in late 1978 as an independent body. It was sponsored by interested organizations and supported principally by private foundations. The Commission was charged to study the relationship between the government and the research universities, to determine the nature and origins of the problems afflicting the relationship, and to recommend ways to solve these problems. Additional information on the origins and purposes of the Commission is contained in the Foreword (p. ix).

Funding Mechanisms

The mechanisms through which the Federal government supports research performed in universities are operational embodiments of government policies. The success of the government-university research partnership depends critically on the degree to which these funding mechanisms are properly suited to the policies, purposes, and expectations of both partners. In this document, the Commission surveys the system of funding mechanisms currently in use, identifies problems in the system, and presents conclusions and recommendations for its improvement.

The Introduction (p. 1) describes the historical development of Federal government interest in support of research, particularly research performed in universities. The next section (p. 5) provides an overview of the system of funding mechanisms currently used to support academic research and describes the strengths and weaknesses of the system from the points of view of the government and the research universities. Next, specific problems in the current system of funding mechanisms are described (p. 15), including difficulties in the array of funding mechanisms and difficulties in the funding instruments which are a part of the mechanisms. Also discussed is the growing issue of university-based research centers and their potential effects on the character of the research universities (p. 23). Next, the Commission's conclusions are presented (p. 25). The final section contains an explanation of each recommendation (p. 29).

Conclusions

The Commission derived several conclusions from its study (p. 25).

1. *Essential Elements.* Several key elements are essential to effective functioning of the research support system, including agreement about purposes, diversity, and provision for new ventures and sustaining research capacity.
2. *Character of Agreements.* Government-university research agreements should include appropriate characteristics such as tailoring to the nature of the performer as well as the sponsor, and utilizing the predominant mode of assistance rather than procurement.
3. *Problems.* While the current funding mechanisms are basically sound, significant unresolved problems remain.
4. *Continuing Experimentation.* An effective system of mechanisms must adapt to changes in the needs and the environment. Revisions and experiments with improvements should be undertaken regularly.

TEAR SHEET—EXECUTIVE SUMMARY REPEATED ON PAGE xi

5. *Mismatched Expectations.* A small number of policy issues remain a frequent source of mismatched expectations, particularly at the operating level. These include the appropriate means for developing research personnel and cost sharing by sponsors and recipients.
6. *Complexity.* The government-university research enterprise is so complex and varied that problems can be oversimplified and solutions misjudged. Care is required in developing changes which will attain intended benefits.
7. *Forum.* The preliminary suggestion made earlier by the Commission of a Forum of individuals concerned with the government-university research relationship has been well received. Further discussion to refine the concept is needed among interested parties.

Recommendations

1. *Equipment Obsolescence*
   The Commission recommends that the federal agencies and the universities adapt funding mechanisms and improve priority-setting strategies to solve the growing problem of research equipment obsolescence.
2. *Stability, Continuity, and Flexibility*
   The Commission recommends that Congress and the federal agencies develop and implement means to increase the stability, continuity, and flexibility of research support while retaining the capacity to respond to changing national priorities. The Commission offers several specific recommendations to this end:
   - (a) The Commission recommends that Congress consider making a transition to a two-year appropriation cycle for those agencies and components of agencies which support basic research.
   - (b) The Commission recommends that those agencies and components of agencies which support basic research lengthen the average duration of their basic research support agreements to at least two and preferably three years, if they have not already done so.
   - (c) The Commission recommends that agencies experiment with authorizing program officers to award a limited number of non-renewable extensions of support at approximately the same level, without full renewal proposal submission and peer review.
   - (d) The Commission recommends the introduction of incentives for funding agencies to provide more timely notices of awards.
   - (e) The Commission recommends that agencies which fund large research programs build in forward-funding mechanisms or devise new ways to cushion the impact of termination of support.
3. *Research Capacity and Initiatives*
   The Commission recommends that the government and the universities work together to develop or adapt a funding mechanism to sustain the research capacity of universities, especially their capacity to undertake new research initiatives.
4. *Assistance As the Predominant Approach*
   The Commission recommends that the Federal government and the universities adopt the policy that assistance rather than procurement is the appropriate mode for support of university research, except where unusual circumstances specifically justify the use of the procurement mode.
5. *Experimentation with Mechanisms*
   The Commission recommends experimentation with new concepts in funding mechanisms as the government-university research relationship evolves. In particular, the Commission recommends experimentation with grants-in-aid managed at the local level.
6. *Cooperation within Institutions*
   The Commission recommends that the universities and the government seek ways to promote intra-institutional cooperation in all aspects of research operation. The Commission offers some specific recommendations toward this objective:
   - (a) The Commission recommends that Congress authorize and the agencies develop arrangements for aggregating research projects for post-award administrative purposes.
   - (b) The Commission recommends that the universities make concerted efforts to reduce internal friction and misunderstanding about indirect costs through education and full discussion of issues.
   - (c) The Commission recommends that the method used by the National Institutes of Health for reimbursing indirect costs be adopted by the National Science Foundation and other agencies which interact significantly with universities.

7. *Cost-Sharing and Matching Requirements*
   The Commission recommends that Congress, the agencies, and the universities reexamine the rationale for cost-sharing and matching requirements in federal programs for support of research in universities to assure that any such requirements are constructive in furthering the mutual objectives of the government-university research relationship.

8. *Additional Science Indicators*
   The Commission recommends that the Office of Science and Technology Policy and the National Science Foundation (a) develop, employ, and report additional science indicators which reflect the balance and diversity of federal research funding programs and (b) encourage the general use of these indicators in research policy development and planning by government and universities alike.

9. *Growth of Research Centers and Institutes in Universities*
   The Commission recommends that the research universities, individually and collectively, examine carefully the implications for university development, structure, and governance of the growth of university-associated research centers and institutes.

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FUNDING MECHANISMS:

Balancing Objectives and Resources in University Research

National Commission on Research
May 1980

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Foreword

The National Commission on Research is a private, nonprofit organization established to examine the relationships between government agencies and universities involved in research and to develop specific recommendations for improvements. The Commission was founded in the latter half of 1978 by the American Council on Education, the American Council of Learned Societies, the Association of American Universities, the National Academy of Sciences, the National Association of State Universities and Land-Grant Colleges, and the Social Science Research Council. The Commission works independently of its founders to examine the process by which the Federal government supports academic research and to propose changes designed to improve that process.

Funding has been obtained for Commission activities to pursue this task from the following organizations: Carnegie Corporation of New York, Exxon Education Foundation, Ford Foundation, the William and Flora Hewlett Foundation, the Andrew W. Mellon Foundation, the National Science Foundation (Grants Nos. PRM-7905778 and CDP-7926386), the U.S. Department of Energy (Grant No. DE-FG01-80ER10167) and the Air Force Office of Scientific Research (Grant No. AFOSR-ISSA-80-00030). Over three-fourths of the funding was made available by the five private agencies and approximately one-fourth from the public sources. Any opinions, findings, conclusions, and recommendations expressed in this publication are the sole responsibility of the Commission and do not necessarily reflect the views of any of the aforementioned funding sources or founders.

This publication on funding mechanisms is the second in a series of documents to be developed by the Commission to analyze the process of government funding and university involvement in research and to make recommendations to all affected parties for improvements in the system. Subcommittees of the Commission are investigating each of the following issues:

(1) Accountability;
(2) Peer review and other selection processes;
(3) Alternative funding mechanisms;
(4) Industry/university/government relationships; and
(5) Development of research personnel.

Position papers on each topic will be published by the Commission.

The members of the Subcommittee on Alternative Funding Mechanisms are Dale R. Corson, Chairman; Donald N. Langenberg; and Linda S. Wilson.

In addition to surveying the available literature, subcommittee members and staff meet with selected officials from business, government, and the universities. At monthly meetings, invited speakers present their views on pertinent aspects of the listed topics or on the broad purview of the Commission. The Commission has received testimony on five university campuses from faculty members and administrators, as well as written comments stemming from invitations to research universities and from an open letter in *Science* magazine. Liaison with numerous government agencies is maintained through telephone contacts, correspondence, and attendance at Commission meetings. Approximately one hundred fifty persons have given advice and information to assist the Commission in its study thus far. The Commission appreciates the efforts of all the participants in its deliberations and discussions. A description of these considerations and a partial list of individuals are contained in the Appendix.

The members of the Commission are listed inside the front cover. These individuals have backgrounds in education, business, and government. They have accepted appointments to serve on the Commission without compensation. During Commission deliberations, they reflect their own experience and not necessarily the viewpoints of their institutions or organizations.

Liaison persons have been designated to the Commission by the following government agencies: Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA); Department of Defense (DOD); Department of Energy (DOE); Department of Health, Education, and Welfare (DHEW); General Accounting Office (GAO); National Aeronautics and Space Administration (NASA); National Institutes of Health (NIH); National Science Foundation (NSF); Office of Management and Budget (OMB); and Office of Science and Technology Policy (OSTP).

In its series of publications, the Commission will review the key elements of the present state of federally supported university research, affirm what it believes to be good in this system, analyze problem areas, and provide suggestions for actions to alleviate these problems. The Commission recognizes that much diversity exists in the complex relationships among principal investigators, research administrators, and others in the university community, and program officers, auditors, administrators, and other government personnel. There is a wide range of beneficiaries, including industry, students, and the general public. The goals of the participating government organizations and educational institutions and of the concerned individuals involved in federally supported research are diverse and sometimes overlapping but not identical. Therefore, the Commission does not anticipate the ability to establish consensus on all of the issues. The Commission does seek to make a contribution to improved research in our nation by improving a system which produces a major portion of that research.

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Introduction

The United States government has played an active and often strongly debated role in the encouragement and support of research since the earliest days of the Republic.[1] The subject was discussed at the Constitutional Convention, with the result that the Constitution empowers Congress to "promote the Progress of Science and useful Arts," but then appears to narrow that power by specifying how, ". . . by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries."

In 1803, Congress appropriated funds in the amount of $2,500 to support a multidisciplinary investigation of the upper Missouri River. One of the project's principal investigators, Meriwether Lewis, broadened his expertise in preparation for the expedition by studying celestial navigation, zoology, botany, and ethnography with the learned members of the American Philosophical Society in Philadelphia. The Congress was evidently persuaded of the potential value of this study by President Jefferson's argument that it was "for the purpose of extending the external commerce of the United States," while at the same time being assured that this foray into foreign territories would be viewed by Spain and France as a mere "literary pursuit." To the Spanish minister Jefferson asserted that the expedition would "have no other view than the advancement of geography," while noting that in presenting his proposal to the Congress it would be necessary to "give it the denomination of mercantile, inasmuch as only in this way would Congress have the power of voting the necessary funds; it not being possible to appropriate funds for a society, or a purely literary expedition. . . ." Congress' rather modest direct appropriation was not the whole of the project's federal support; salaries and supplies were provided by the War Department.

Readers familiar with the research enterprise of the United States today will be struck by the way in which this early example of federally supported scientific exploration presages certain features of the modern scene. There is the use of expert advice from non-government scientists, the justifications in terms of practical benefit to a wary Congress and of scientific benefit to other interested parties, and the participation and support of a military service in the pursuit of objectives transcending any purely military mission. Additionally, there is the retrospectively evident importance to the nation of an exploration which before the fact must have seemed to many to be a frivolous waste of public money.

Other salient features of today's national research effort can similarly be traced to early origins. The Army and the Navy played prominent parts in the exploration of the continent and of the seas around it and sporadically supported science in support of their missions throughout the nineteenth century. In 1863, the National Academy of Sciences was founded, espousing as one of its purposes the bringing of science to the service of the government. A year earlier Congress had passed the Morrill Act, "donating public lands to the several States and Territories which may provide colleges for the benefit of agriculture and the mechanic arts." In 1887, Congress followed with the Hatch Act, providing federal support for agricultural experiment stations associated with the land-grant colleges developed as a result of the Morrill Act. These two legislative actions for the first time established the Federal government as a partner with academic institutions in a broad-based program to enhance the national welfare through research. The fruits of this century of partnership are no less astounding for being taken for granted by most American citizens. It has given the United States its original and perhaps most bountiful technology, American agriculture, which leads the world and is a major source of national strength.

The advent of the twentieth century brought a quickening of the pace of federal involvement in the support and performance of research. Two milestones among many are the establishment of the National Bureau of Standards in 1901 and the transformation of the Public Health Service's Hygienic Laboratory into the National Institute of Health in 1930. By the outbreak of World War II, the Federal government had become a major factor in the American research enterprise. The striking successes of that enterprise during the war are a familiar story. They led, after the war, to renewed public debate of the nature of the federal responsibility for support of scientific research. The character of this debate owed much to Vannevar Bush's eloquent arguments for the importance of public support for science and scientific institutions, presented in his report to the President, *Science—The Endless Frontier*. The debate resulted in the creation of the National Science Foundation in 1950.

The three decades since 1950 have brought an explosive expansion of federally performed and supported research. The nation currently invests about $50 billion (about 2.2 percent of the Gross National Product) annually in research and development (R&D); of this about half comes from the Federal government. Basic and applied research (the R in R&D) typically account for one-third of total national R&D expenditures; about two-thirds of the research total is for applied research, one-third for basic research.

One of the most significant features of the development of the national research effort since World War II is the emergence of the research universities as the principal performers of basic research. This was not accidental or unintended, but the result of conscious national policy decisions epitomized by the creation of the National Science Foundation with its mission "to develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences; and to initiate and support basic scientific research in the mathematical, physical, medical, biological, engineering, and other sciences. . . ." The research universities had embraced research as one of their principal missions since the latter part of the nineteenth century but, with the exception of agricultural research, had pursued this mission independent of any substantial government support before the late 1940s.

Today the situation is very different. The research universities of the nation number 50 to 150, depending on the criteria used. These institutions account for only about 10 percent of total national R&D expenditures but more than 50 percent of total national expenditures on basic research. The basic research figure rises to 60 percent if expenditures by federally funded research and development centers (FFRDC's) administered by universities are included. About three-quarters of the funds spent by universities on basic research are provided by the Federal government. Thus, over the last three decades the United States has moved purposefully to vest the greatest share of the responsibility for the creation of new knowledge, the seedbed of future technology, in a government-university partnership.

It is important to understand that this partnership is neither simple nor inevitable. On one side, there is the Federal government embodied in a diverse array of agencies, each with its own mission and its own perspective on the purposes of research. On the other side, there is a diverse array of research universities, some private and some public, but none a federal institution. With few exceptions, every agency and every university has functions, obligations, and constituencies which have little to do with the research which is the common concern of the partnership. This arrangement is almost uniquely American. Other countries have taken different paths. In most, all universities are government institutions and in many, institutions of the central government. In many, the system of basic research performers includes and is often dominated by publicly supported research institutes more or less unrelated to any university.

Any serious contemplation of the American system for the investment in and conduct of research and development raises many questions and issues. The federal role in this system particularly highlights these aspects. Few are new, and many first appeared in the earliest days of the nation. Among them are:

- Does the Congress have the power to provide funds in support of research? This constitutional question was actively argued in the early decades of the Republic. It appears to have been settled in the affirmative.
- Should Congress provide funds in support of research? This question also appears to have been settled in the affirmative, but more recently, and consensus on the question is far from complete.
- For what purposes should Congress provide funds in support of research?
- At what level should Congress provide funds in support of research?
- What is the best balance among basic research, applied research, and development?
- What is the best balance among different fields of science and technology?
- What is the best balance among federal agencies?
- What is the best balance among types of research performers?
- What is the best balance among types of support, e.g., support for specific projects, broad programs, institutions, or training of individuals?
- What should be the nature of the funding relationships between the Federal government and research performers?

All but the first of these questions have long been and can be expected to remain active subjects of national debate. The purpose of this report is to examine some of them in the context of a single element of the national research and development enterprise, the government-university partnership which has assumed the major responsibility for basic research. The report further focuses on one aspect of the partnership, the mechanisms through which the government provides and the research universities use public funds to support and perform research. It does so because these funding mechanisms are the operational embodiments of government policies toward university research. The success of the government-university research partnership depends critically on the degree to which the funding mechanisms are properly fitted to the policies, purposes, and expectations of both partners.

Over the past decade a variety of pressures and problems have led to increasing strain in the partnership. As detailed in the Foreword (p. ix), the independent National Commission on Research was established to review the state of the government-university research system and to seek ways to relieve the strains which have evolved. This report is the distillation of Commission thought on the issue of funding mechanisms and its bearing on the problem of reducing the strains and making the system more effective.

In the next section, the system of funding mechanisms currently used to support academic research is reviewed and comments are made on strengths and weaknesses of the various mechanisms from the points of view of the government and the research universities. This is followed by an examination of problems and issues in this system. The essential features of a good funding mechanism are described, as viewed by the Commission. The report then states conclusions of the Commission which identify ways in which the system can be improved and presents a series of recommendations for implementing the necessary changes.

Current System of Funding Mechanisms

An Overview of the System

Funding Mechanisms

In the years since World War II, many different mechanisms for the support of academic science have evolved, and many different federal agencies now participate in that support. The Commission has collected data about the forms of support used by various agencies and the amount of support by agency and by mechanism. It is important to collect such data and to analyze support by various agencies as the Commission has done because the relative emphasis placed by the various agencies on the differing forms of support is a statement of federal research policy. For example, to the extent that an agency has as its primary objective the strengthening of basic science and the support of individual scientists, the small research grant will be prominent. On the other hand, where the emphasis is on specific technological goals and the application of science and technology to societal problems, there will be greater reliance on research contracts and the support of research centers built around specific objectives.

Table I[*] shows the federal funds expended for university-performed research and development in Fiscal Year 1979. These are classified by agency source and by type of funding mechanism. There are listed below the six general mechanism types in our classification scheme.

Individual Research Projects

In this type, grant or contract awards are made to support work by a small number of investigators, often a single person. Awards are normally made to the investigator's university and are typically small relative to awards made through other types of funding mechanisms. This classification sets a rather arbitrary upper limit of $150,000 per year in defining an award as an individual research project. Such awards are based on proposals made by one or a few principal investigators. The research objectives are usually defined by the investigator rather than by the agency, and proposals are commonly evaluated through a peer review system. Most project research is performed within disciplinary departments of a university. Individual research project support accounts for almost half of all federal support for university research and development. Most of the work supported by this mechanism is basic research.

Research Programs

Where federal support is for a broad, coherent area of investigation, usually involving more than one senior investigator, and where the annual support exceeds $150,000, we have classified the support in this category.

Research Centers

Many agencies support university research organizations called "research centers" which undertake a research program in a particular, broad field of interest to the university and to a sponsoring agency. (The Categorical Disease Centers supported by the National Institutes of Health are an example.) The management of the center and coordination of specific research projects into a coherent research program are delegated to the university. Proposals for specific research projects carried on in the center may or may not be reviewed or approved individually by the federal agency.

Research on Problems Set by a Federal Agency

Federal agencies often identify areas within which they wish to have research or development performed and then seek proposals from prospective performers. The research is often of an applied nature, and the specification of the work to be performed is usually more tightly drawn than is the case in research centers. The support instrument is usually a contract rather than a grant.

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[*] The Commission is indebted to Dr. Charles V. Kidd of The George Washington University for help in compiling these data.

TABLE I:
FEDERAL FUNDS EXPENDED FOR UNIVERSITY RESEARCH BY AGENCY AND BY TYPE OF SUPPORT, FY 1979
(in millions of dollars)

					Large R&D Contracts			
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Agency	Total	Traditional Small Research Projects (Grant or Contract)	Substantial Research Programs	Research Centers	R&D on Problems Set by the Federal Agency	R&D Conducted in Very Large Facilities	Broad Institutional Support	Other
Total	$3,833[1]	1,813	465	551	492	159	250	95
NIH[2]	1,770	897	210	315	210		52	86[3]
NSF	602	494	42	32		34		
DOD	364	176	73	43	39	33		
HEW (other than NIH)	163	70	25	28	33			7
Energy	292	35	60	70	57	70		
Agriculture	206	15					191	
NASA	144	68	21	19	30	6		
AID	67	3	5	8	51			
EPA	50	3	8	10	29			
Interior	40	3	5	10	12	10		
Commerce	29	3	6	4	7		9	
DOT	19	6			13			
Other[4]	87	40	10	12	11	6	6	1

[1] Source: Special Analysis of the Budget of the U.S. Government, 1981, Special Analysis K. Research and Development, p. 311.

[2] Distribution by type for NIH assumed to be the same as in FY '78, which is the last year for which NIH has analyzed grants and contracts by type.

[3] Research career awards; minority biomedical research support.

[4] Distribution by type of support assumed to be the same as the distribution of all other agencies combined.

Large Facilities

This category refers to organizations which differ from research centers in that they are based on large, special, physical facilities or instruments, such as a high-voltage electron microscope or a nuclear reactor. The sponsoring agency often requires that the facility be made available to investigators from other universities. Contracts are normally used to finance these facilities, with provisions which enable the sponsoring agency to monitor closely the operation and use of the facility.

General Research Support

In this type of funding mechanism a federal agency provides funds to an organization to perform research in some general area or to maintain or strengthen its research capability. At present only two federal agencies provide such general research support, the Department of Agriculture (USDA) and the National Institutes of Health (NIH). The Department of Agriculture provides funds authorized under the Hatch Act for research in agricultural experiment stations. These funds must be matched by state appropriations. The experiment stations are attached to land-grant universities and have a relatively free hand in determining the specific research to be undertaken so long as it is agricultural research.

The National Institutes of Health Biomedical Research Support Program grants funds to eligible institutions for general support of health-related research in the biomedical sciences. The grants are awarded on a graduated formula basis related to the annual total amount of Public Health Service research project grant support awarded to the institution. An entitlement threshold and a ceiling limit the number of recipients and the size of the award. The program currently makes approximately 400 awards ranging from $25,000 to $200,000. Responsibility for allocation of the funds among eligible users is delegated to the grantee.

For a number of years the National Science Foundation (NSF) also awarded institutional grants for science on a formula basis, related to the total federal project research funding awarded to the institution. This program was discontinued in the early 1970s.

In the 1960s, the National Science Foundation provided another type of broad institutional support through a University Science Development Program and a Departmental Science Development Program. These programs were designed to develop "new centers of excellence." The Science Development grants were typically $5 million spread over a few years. The intent was to strengthen a major part of a particular university's science effort, and the grants usually embraced several departments of the institution. The Departmental Science Development Programs, on the other hand, focused on individual departments. Both types of grants were distributed widely around the country and were intended to benefit universities which were in a stage of development where substantial new funds could have maximum impact on the scope and quality of research effort. Universities which already had large, high quality programs and universities believed to be incapable of building significant quality with the funds available were not considered for these awards. These NSF programs also were eliminated in the early 1970s.

The two other types of funding mechanisms which follow are not included in the tabulation of Table I but are important components of federally funded university research.

National Laboratories

A considerable number of national laboratories have been established to perform research and development in major areas of national interest. These typically have their own large professional staffs which perform research, but they also develop and operate facilities which are used by university researchers from all over the nation. These laboratories include the Fermi National Accelerator Laboratory in Batavia, Illinois; the Brookhaven National Laboratory on Long Island; the National Radio Astronomy Observatory with sites at Charlottesville, Virginia, Green Bank, West Virginia, Socorro, New Mexico, and Kitt Peak, Arizona; the National Astronomical Observatory at Kitt Peak, Arizona; the National Center for Atmospheric Research at Boulder, Colorado; and others. These laboratories are usually operated by consortia of universities under contract to a federal agency.

Training Grants and Fellowships

Some federal agencies grant funds to universities or to individuals to support predoctoral or postdoctoral research training. The primary purpose of such grants is to assure the future availability of well trained researchers in general or specific areas where a national need is perceived. However, since individuals can be trained to do research only through actually doing research, training grants and fellowships contribute to the research productivity of the institutions in which the training takes place. Most such training is conducted at universities.

Other Mechanisms

The categories described above are quite broad. Within these categories the federal agencies have developed a versatile array of distinct programs tailored to meet specific needs. For example, NIH has developed the Research Career Development Awards, which provide a period of uninterrupted research time to encourage and strengthen investigators of exceptional promise. NSF has developed doctoral dissertation grants to strengthen the quality of dissertation research in certain fields. NIH, NSF, and DOE (Department of Energy), have developed ways to aggregate closely related research projects into a research program via their "program project grants," "coherent area grants," and "cluster grants," respectively. NIH, NSF, and DOE offer special research initiation programs for new investigators. Many other examples could be cited.

Funding Instruments

In addition to the types of funding mechanisms described above, the various funding instruments used for the support of research also must be considered because the nature of the funding instrument can profoundly affect the performance of the supported activity. The principal instrument types are grants, cooperative agreements, and contracts. Other funding instruments are theoretically possible, such as loans, loan guarantees, and subsidies, but these generally have not been used to support research in universities. Each of the principal types has a number of variations which differ with regard to the basis on which funds are provided, the degree of federal involvement in the definition and technical performance of the supported activity, and the specificity of the purpose of the contractual relationship. For example, the funds may be provided on a cost reimbursement, grant-in-aid, or formula basis and involve various degrees of cost participation by the recipient. The degree of federal involvement may be minimal; it may involve shared direction and control; or it may involve federal oversight.

The federal procurement system for acquisition of goods and services for the benefit and use of the Federal government has evolved over many years. A comprehensive set of procurement principles and procedures has been developed, tested, and revised. A substantial body of procurement case law exists. Federal assistance programs, however, are a much more recent addition. No comprehensive system exists for their guidance and management. Nor has there been, until recently, any clear guidance regarding the appropriate choice of funding instrument for a given purpose. The result has been confusion in terminology and concepts, inconsistent practices, mismatch in expectations of performer and sponsor, and misunderstanding, especially regarding the nature and purpose of grants. Because the boundary between procurement and assistance has not been well understood, procurement-based requirements have frequently been used in assistance situations.

In 1972, the Government Procurement Commission recognized these problems and recommended that a study be undertaken to examine the feasibility of establishing a comprehensive system of guidance for management of federal assistance programs. The Federal Grant and Cooperative Agreement Act of 1977 (Public Law 95-224) codified that recommendation and mandated a study which has been completed just recently. In the intervening years, federal assistance programs have increased manyfold, primarily in assistance to state and local governments. Federal assistance activities are now carried out through more than 1,100 programs with an annual budget of over $100 billion, more than 85 percent of which is awarded to state and local governments.

The Federal Grant and Cooperative Agreement Act established two dichotomies: first, between assistance and procurement; and second, to divide assistance based on the involvement of the government in performance of the activity. The Act then mandated the use of contracts for procurement, grants for assistance without substantial involvement of the government, and cooperative agreements for relationships where the government is substantially involved.

Strengths and Weaknesses of the System

Funding Mechanisms

The objective assessment of the strengths and weaknesses of the system of mechanisms through which the Federal government supports university research is a difficult task. The difficulty is rooted in fundamental differences in objectives, functions, and philosophy between the government and the universities, and in the great diversity of agencies and institutions on both sides of the partnership.

The Federal government has for nearly two centuries rather consistently taken the position that it should support research only where the results of that research can be expected to satisfy a clearly identifiable national need. Jefferson's Congress was willing to support exploration "for the purpose of extending the external commerce of the United States" but not as a mere "literary pursuit." The Federal government long avoided any substantial involvement in education; George Washington's personal offer of an endowment for the establishment of a national university which would, *inter alia*, provide advanced scientific training, was rejected by Congress despite support by Jefferson and Madison. Support of learning for its own sake or of intellectual institutions as centers of national culture have never been popular notions in Washington. The tensions between the Federal government and the states, between elitism and populism, and between the theoretical and the practical, which have molded so much of the American character, have also strongly influenced the government-university research endeavor. The government funds research in support of its responsibilities for the security and welfare of the nation. Most federal agencies which support research have specific missions addressing one or more aspects of the government's responsibilities. In the cases of the National Science Foundation, the National Endowment for the Humanities (NEH), and the National Endowment for the Arts (NEA), the federal agencies' responsibilities are more broadly and generally defined than Jefferson's Congress might have found to his liking.

The extraordinarily fruitful collaboration between university scientists and the government during World War II led to the recognition of the potential of such cooperation for the public welfare. Our nation has also come to recognize both the importance of long-term investment in basic research and the relationship of scholarship and the arts to the intellectual and moral fiber of our people. Nevertheless, the fundamental interest in tangible results which promote the national welfare is never far below the surface.

Because of this basic federal philosophy, the federal agencies which support research tend to seek certain characteristics in funding mechanisms. There is a desire for control, equity, and consistency. There is a natural predilection for the more applied, the more predictable, and the lower risk research. In some cases, these desires lead agencies to treat expenditure of funds for research in the same way as expenditure of funds for the procurement of pencils or ships. In all cases, the need for proper accountability to the citizenry, in matters both scientific and financial, imposes constraints which an acceptable funding mechanism must satisfy.

The research universities operate from a different tradition and philosophy. Research and scholarship are commonly viewed as important ends in themselves, worthy of support, together with the institutions which nurture them, as a general public good without consideration of immediate practical usefulness. In matters of research and scholarship, the best is so incomparably better than the second best that universities put great emphasis on quality. Creativity is so highly valued that universities vest their researchers and scholars with considerable independence and freedom in choosing what research they will do and how they will do it. The universities' monastic origins and their modern status as non-profit, private institutions or as public wards of a state place most of them in delicate financial positions, subject to the fluctuating fortunes of a host of different patrons and clienteles.

The research universities thus often seek different funding mechanism characteristics than do the federal agencies. Flexibility to exploit scientific opportunities is important. Emphasis on scientific merit may lead to concentration of the available resources in the hands of a few outstanding researchers rather than spreading them widely among many. There is a tendency to regard most highly the more fundamental research and work with higher risk and higher scientific payoff. Where a university has come to depend heavily on federal support for its research effort, as most major research universities have, stability of support over time is important. Although most research universities invest substantial amounts of their own resources in support of research, the magnitude of these research efforts creates the need to maximize recovery of research costs from federal sponsors. The maintenance of close links between research and teaching, and the minimization of administrative burden are also important university objectives.

These differences between the objectives and perceptions of government agencies and the research universities mean that a particular feature of a funding mechanism may be a strength to an agency and a weakness to a university, or *vice versa*. As this report discusses the funding mechanisms defined above, it endeavors to describe them from both points of view.

Individual Research Projects

The backbone of the American science system which is conducted in universities is the individual project grant or contract, with almost half the entire federal support for academic science provided through this mechanism (cf. Table I).

There are many advantages to the individual project scheme. It gives an opportunity for a large number of investigators to seek federal funds on a competitive basis. The most worthy proposals, judged in a peer review system where the most informed scientific judgment can be brought to bear, can be selected for support. The relatively modest funding level typical of individual project grants or contracts permits support of a large number of individual investigators; this mechanism thus can distribute support relatively widely. The mechanism also provides an opportunity for many different agencies to support programs of interest to them. By supporting a large number of relatively small projects, federal agencies can have the flexibility to shift emphasis in research programs without disrupting large research enterprises. For a large research university, as many as 1,000 to 2,000 such projects is not uncommon. In these circumstances, fluctuations in total institutional funding will tend to be relatively small, therefore providing the appearance of stability. However, funding fluctuations at the level of individual investigators can be large.

On the other hand, the project system is a "retail" system, requiring decisions on tens of thousands of relatively small grants per year, and therefore involves a large amount of administrative detail for both the government and the universities. Each grant constitutes a separate agreement between a sponsor and a performer. Each requires individual review as well as scientific and financial accounting and reporting. This tends to segregate funds and scientific effort in small, impermeable compartments and creates a certain amount of rigidity and inflexibility. The system shifts to universities and academic departments the burdens of providing the resources required for the common support of many investigators, for coping with awkward gaps in research support, for supporting individuals and their research during periods when they have little or no external support, for helping younger investigators get started in research, for developing and maintaining research capacity, and for maintaining a proper balance among fields. These burdens are a necessary byproduct of the individual projects system, but institutional and external resources for addressing these needs have been sharply curtailed in recent years.

Research Programs

Although we have distinguished research programs from individual research projects in order to present a complete picture of the array of funding mechanisms, the strengths and weaknesses of the two mechanisms are similar. The larger size of research programs relative to individual research projects can reduce administrative burden for federal agencies, researchers, and their institutions. It can also increase the researchers' flexibility but may decrease funding stability in the institution.

Research Centers

Academic research, particularly in the sciences, encompasses much more than the basic research performed by individual investigators. Most major national research universities perform both basic and applied research, some of it requiring large and expensive physical facilities. Some of this work is carried on within academic departments, and agencies make large grants to departments, or to groups within departments, on a "wholesale" basis. In these cases, the departments or groups are responsible for the "retail" funding allocation decisions necessary in the execution of the research projects. DOE- and NSF-funded high energy physics and nuclear physics groups within university physics departments provide examples of this funding mechanism. In such cases, the peer review process includes a significant intra-department or intra-group element, and questions can arise about its breadth and objectivity. With competition for federal funds decided at the local level, intra-departmental relations may be strained.

The federal objective often involves research programs for which an academic department is not the best form of organization for pursuit of the research. To provide appropriate organizational arrangements in these cases, nearly every major research university has an array of research institutes, laboratories, or centers designed to bring multidisciplinary and interdisciplinary skills to bear on such research. These centers, whether based on a single discipline or several disciplines, can provide common services for a large number of investigators. Where center funding sources permit, a center can provide flexibility for individual investigators to change direction quickly when new research opportunities arise, as well as initial funding for young investigators and for mature investigators who wish to enter a new area of research.

University organizations for the performance of large scale research usually include a director who may be full or part time, and they usually provide for local policy guidance by a policy or administrative board. The organization generally provides for internal peer review as a part of the local funding allocation process. Federal oversight is commonly exercised through prior agreement with the institution about research focus, through external peer review of center proposals, and through periodic site visits by agency officials and external peer reviewers.

From the standpoint of the federal agencies, centers or similar, organized research units are an effective way of mobilizing universities for research work on problems of significance to the agency. However, there can be difficulties between the sponsoring agency and the university if the mission of the center is not clearly stated and mutually understood. Centers tie up large amounts of agency funds for long periods. While this is advantageous from the research support stability standpoint, it decreases the flexibility of the federal agency and limits the number of new directions the agency can undertake.

From the standpoint of the universities, centers offer a means of mobilizing resources more effectively than is possible within academic departments. Departments bear the responsibility for the curricular and teaching functions of the institution and provide the foundation for the system of faculty appointments and tenure. This gives the departments permanence but also a degree of rigidity. On the other hand, a proliferation of centers can blur the authority of administration in the universities.

Also from the standpoint of the university, major problems are apt to be generated when funds are withdrawn. The termination after Fiscal Year 1971 of the university centers funded for a decade by the National Aeronautics and Space Administration (NASA) in its Sustaining University Program is a case in point. The problem becomes particularly acute if tenured faculty members are supported on center funds. Many universities have elected to keep tenured faculty members on "hard" university money, and some universities have even established reserve funds in anticipation of possible withdrawal of federal funds.

The central research support services which the university has built up through the use of indirect cost reimbursements to meet the needs of a center are apt to represent a burden if the center is closed. Such services can rarely be dismantled or reduced as rapidly as the center's external support can be phased out.

The prospect of large scale support has sometimes led universities to accept support for a center without full consideration for the administrative responsibilities and complexities involved. Substantial financial risk is accepted when a grant or contract for a large center is accepted. Such agreements normally include termination clauses, usually providing for termination at the convenience of the government, with provision for reimbursement only of immediate termination costs.

While many university centers are supported through a combination of relatively small project and program grants, a number of federal agencies support large research efforts in specified areas at particular universities with block grants. These are grants which may include annual support of up to several million dollars awarded to the university, with the detailed administration of the grant delegated to the institution. Research programs supported with such grants include the National Science Foundation Materials Research Laboratories, created and originally funded by the Advanced Research Projects Agency of the Department of Defense (DOD); the National Institutes of Health Categorical Disease Centers; various large high-energy and nuclear physics research programs, some supported by the Department of Energy and some by the National Science Foundation; and the Department of Interior's Water Resource Research Centers.

The materials sciences provide a rare opportunity to assess the relative advantages and disadvantages of block-funded research centers and individual research project funding, because in this research area both mechanisms are used to a substantial extent. In 1978, the MITRE Corporation completed a massive comparative study of materials research conducted in the National Science Foundation's core-funded Materials Research Laboratories (MRLs) and materials research supported by project grants in other institutions. In the latter group, some institutions had separately organized Materials Science Centers and some did not. Also included were several interdisciplinary laboratories (IDLs) supported by the Department of Energy. The major conclusions of this study were:

- Universities with MRLs have a better capability (in terms of faculty and equipment) to perform materials research than non-MRL universities without Materials Science Centers. The capability of non-MRL universities with Materials Science Centers is much like the MRLs.
- From the viewpoint of total (university and NSF) administrative time and costs involved in administering grants, the MRL core grant mechanism is much more efficient than the project grant mode.
- About 70 percent of the materials research areas sponsored by NSF at the institutions surveyed show no overlap between MRLs and project-funded institutions.
- Research at the MRLs is more heavily oriented toward experimentation than research at non-MRLs without Materials Science Centers.
- There are no significant differences between MRLs and non-MRLs in concentration of funding, annual rate of turnover in research areas, duration of research areas, and continuity of staffing.
- The review of research publications does not show a clearcut dominance of one population over the others being compared. There is no statistically significant difference at the 90 percent confidence level among any of the populations with respect to interdisciplinarity and overall indicators of innovation. In quality of procedures, the NSF core-funded papers rank higher than project-funded ones. In contributions per paper to research or technology NSF core-funded papers rank lower than project-funded. In the use of essential specialized equipment, excluding computers, core-funded papers rank higher than papers from non-MRLs with Materials Science Centers but lower than papers from DOE/IDLs.
- Citation analysis shows that only NSF/Project-funded papers at MRLs were cited with significantly greater frequency than MRL core-funded papers. The latter were cited with about the same frequency as papers from DOE/IDLs and NSF/non-MRLs without Materials Science Centers.
- In major achievements, the MRLs have much more than a proportional share (based on total NSF funding) rated in the top 15 percent. However, the MRLs have slightly less than a proportional share of achievements rated in the top 25 percent.[2]

These conclusions do not demonstrate a clear superiority for one funding mechanism over the other. They do suggest that different funding mechanisms give rise to different ways of doing research and produce different kinds of science, and thus increase the diversity of the national research effort and expand the range of new knowledge available for application.

Research on Problems Set by a Federal Agency

When a federal agency identifies a problem requiring research, it usually can choose from among a variety of possible types of performer. It may have its own in-house laboratories, or it may consider contracting with a government laboratory belonging to another agency, an industrial laboratory, a federally funded research and development center (FFRDC), a university, or another non-profit research organization. A university may be the performer of choice because it may have special expertise or facilities, because it may offer lower cost, or because secondary benefits such as the training of researchers in a new area may also be valued. On the other hand, a university may be an unattractive choice because its commitment to teaching as well as research and its decentralized structure may make difficult mobilization of its resources within the desired time span.

From the university's point of view, the conditions which accompany an opportunity to work on a strongly focused government project may not be compatible with certain university principles and commitments. For example, the government may seek an unacceptable degree of control over the direction of a project or attempt to impose unacceptable restrictions on publication of results or on personnel matters. In such cases, the university's desire to be of public service must be weighed against the danger of compromising the basic institutional functions of instruction and research. The university's decision to become involved in research programs of this type will depend on the nature of the institution. It will generally be made on a case by case basis with due regard to the overall balance of the institution's research effort and the availability of faculty interested in the particular problem.

Large Facilities

From the government point of view, the establishment of a specialized research facility at a university may have several advantages: it places the facility within a community of skilled users, the environment may be made readily accessible to other users, and there are the collateral benefits of training in advanced techniques for research students. These same factors make the facility attractive to the university. However, the university may find it difficult to provide the managerial capacity required for a large facility and may be unprepared or unable to cover hidden costs which such facilities often entail. Again, some institutions will be better suited to house large facilities than others, and both the sponsoring agency and the university need to be fully alert to all the implications before entering into large facility agreements.

General Research Support

To a federal agency struggling to stretch limited funds over the largest possible range of high quality research, the option of providing funds for general support of research activities of a research organization is often unattractive or at least of low priority. From the agency's perspective, the use of this type of funding mechanism dilutes the agency's direct control over the use of its funds. It raises both concerns about quality assurance and fears that funds may be diverted to non-research purposes. On the other hand, decentralization of some allocation decisions is advantageous for the agency since it can reduce delays and administrative costs and increase the productivity of the funding system.

The universities see general research support as an important element of a balanced research funding system because it allows prompt and cost effective responses to the gaps inherent in the individual research project funding system. Emergencies, unexpected opportunities, new starts, and development of shared resources are typical funding needs which are inadequately addressed by the project system.

Individual investigators have mixed feelings about general research support. While they recognize the importance of the needs it addresses, they fear expansion of general research support at the expense of project support. Their primary concerns are quality assurance and preservation of the relative independence which their relationships with external sponsors provide.

Where local or regional needs and conditions are a key factor in determining what research should be done and how, as in agricultural research, general research support rather than centralized federal project support offers advantages.

National Laboratories

While the national laboratories are not university laboratories in a strict sense, they have a major impact on academic research. The large facilities represented by the national laboratories are usually operated as national facilities through consortia of universities for the benefit of academic research scientists. They are essential features of the scientific research enterprise of the nation. These laboratories provide large and expensive facilities, usually not easily accommodated at universities but vital for research in the fields they represent.

The relative allocation of funds between the national laboratories and university researchers is a frequent matter for debate. In astronomy, for example, approximately three-quarters of the National Science Foundation budget for support of research in astronomy goes to the five national centers or observatories: the National Astronomy and Ionosphere Center (Arecibo), the National Astronomy Observatory at Kitt Peak, the Cerro Tololo Inter-American Observatory, the National Radio Astronomy Observatory, and the Sacramento Peak Observatory. These funds support the operations at the observatories, which are used both by their own research staff members and by university researchers. While few would challenge the essential nature of these large laboratories, there are those who challenge two aspects of their operations. These are, first, the distribution in funds between the national laboratories and individual user projects and, second, a system which is sometimes perceived to afford research support opportunities to the national laboratory permanent staff without the stringent peer review evaluation required for proposals by individual project scientists. As with other aspects of the national research funding system, this is a question of seeking the best balance of characteristics among those available in the competing mechanisms.

Training Grants and Fellowships

Training grants and fellowships have generally been viewed by the Federal government as a means of encouraging the creation of a future supply of investigators rather than as a component of support for current research productivity. Consequently, the level of funding has undergone large fluctuations as perceptions of future manpower needs have changed. Shortly after the launch of Sputnik, the number of federally funded fellowships for scientists increased dramatically. An equally dramatic decrease occurred about a decade later; for example, the total number of fellowships and traineeships in physics went from over 2,700 in 1968 to fewer than 900 in 1975. The number of young investigators produced by our universities has not varied so rapidly nor so greatly as the number of fellowships and traineeships, partly because of the time lag associated with the long time required for development of a college freshman into a fledgling scientist and also because many students find other means of support such as part-time jobs, teaching assistantships, and research assistantships funded through individual research grants. Nevertheless, these large fluctuations in federally funded training grants and fellowships have contributed to instabilities in federally funded university research programs. Variations in graduate student support will continue to be of concern to both the government and the universities in the future. The difficulties of predicting manpower supply and demand and the complex and long delayed effects of any attempt to drive the system through changes in funding for training make this funding mechanism one to be manipulated only with great caution.

Funding Instruments

The assessment of the advantages and disadvantages of the use of grants, cooperative agreements, and contracts as the funding instruments for federally sponsored research in universities is sorely complicated by the variation among funding instruments carrying the same name. For example, an Office of Naval Research (ONR) contract for the support of basic research provides more flexible operation than certain grant arrangements with agencies which have predominantly "assistance" relationships. The dichotomies established by the Federal Grant and Cooperative Agreement Act, between procurement and assistance and between grants and cooperative agreements, yield an array which is neither benign nor malevolent to research. The clarity sought by the grant/contract dichotomy is too elusive to be reached only by the enactment of Public Law 95-224. The practices of agencies and the attitudes of their personnel are the principal administrative determinants of the ability of the awardee to carry out research effectively. Many researchers have made the point in testimony before the Commission that the characteristics and administration of an award (contract) from the Department of Defense are more like assistance than an award (grant) from the Department of Energy.

The attitudes of researchers and university administrators are also a significant factor. Both researchers and university administrators have been influenced by their experience with some agencies' practices in the use of these instruments. Biomedical research, for example, was long supported by NIH via grants. In the early 1970s, that agency markedly increased its use of the contract, a move that caused serious concern in the academic research community. The root of this concern lay primarily in the accompanying shift from researchers to the agencies of the locus of responsibility for deciding which problems were ripe for study, and in the selection of contractors without rigorous peer review. There was also concern about federal involvement in performance of the work and increases in administrative requirements. The NIH move to increased use of the contract mechanism was influenced by the plans for a war on cancer and heart disease and by an increased administrative emphasis on employment of management principles in all facets of federal activity. Much of the biomedical research community questioned the expectations that difficult scientific problems could be solved simply through application of money and management. In their view, this area of research was primarily in need of good ideas which could not be "managed" into existence. Many in the biomedical research community continue to resist or distrust the use of the contract as a result of this experience. The pendulum has recently swung back; NIH now makes much less use of the contract as a funding instrument.

Some contracts, such as those awarded by ONR for basic research, have been flexible enough to nurture exploratory work. Some grants, such as those awarded by the Office of Education and the National Endowment for Humanities, have provided little or no flexibility, especially with regard to internal budget changes during the award period. Some agencies, such as DOE, require in both contracts and grants frequent and burdensome technical and managerial reporting which may be appropriate for demonstration or development work, but which is unnecessary and unproductive for basic research.

Problems in the Current System of Funding Mechanisms

The establishment of the National Commission on Research was motivated by a growing perception among thoughtful observers of the American research enterprise that strains have developed in the government-university research partnership which seriously threaten its vitality. These strains have been discussed and documented by many authors, e.g., B. L. R. Smith and J. J. Karlesky in *The State of Academic Science—The Universities in the Nation's Research Effort*. The Commission has not undertaken extensive independent studies of its own, but has reviewed existing work such as the Smith-Karlesky report, and has interviewed numerous federal officials and university administrators and researchers. A partial listing of these individuals appears in Appendix II. A part of the picture which has emerged from our efforts concerns funding mechanisms. In general, the current system of funding mechanisms is viewed as basically sound and possessed of substantial strength derived from its diversity and flexibility. Nevertheless, close inspection reveals a variety of problems which call for attention from all the participants in the system. The system is not working as well as it could and should.

The shift from rapid expansion of research support through the 1950s and 1960s to the current state of tightly limited resources has necessitated changes throughout the government-university research enterprise and, in particular, this has brought questions of balance among types of research, sponsor, performer, and funding mechanism into sharp focus. Competition among fields of research, among institutional performers, and among individual researchers has become severe. Margins for flexibility and risk taking have dwindled and vanished. New initiatives can be considered only at the expense of continuing programs. Although none of these difficulties are unique to the research enterprise, their effects may be particularly damaging there because research cannot thrive in an atmosphere of stasis and conservatism. In considering specific problems in the funding mechanism system, we must keep in mind that their solution through substantially increased funding in real dollar terms is not likely. Instead, we must look for improvements which can be made within a generally constant funding environment.

The Commission has identified the following specific difficulties.

Difficulties in the Array of Funding Mechanisms

While the array of funding mechanisms includes a remarkable diversity of program types, some elements are missing. The missing elements are illustrated by three types of problems.

A Rapidly Developing Equipment Inadequacy Problem

American science is currently suffering from inadequate and obsolete equipment. Several factors contribute to this situation. First, development of new types of equipment has been unusually rapid in recent years because of the rapid development of measurement and instrumentation techniques. These developments are based in part on rapidly developing computer technology and on the maturation of other equipment technologies based on earlier scientific developments. The availability of entirely new types of equipment opens new opportunities to pursue the unknown, opportunities which cannot be exploited without the equipment. In many fields the ability to work at the frontiers depends entirely on access to the necessary equipment.

Following is an illustrative example: one of the byproducts of nuclear weapons development during and after World War II was the copious production of a variety of radioisotopes. The use of these radioisotopes as tracers in chemical and biomedical research has become a standard tool and has contributed enormously to advances in these fields. The equipment required to use this technique created a significant increase in instrumentation complexity and sophistication in these fields, but was nevertheless on a scale which could be afforded and used by individual investigators. The technique is not without disadvantages, not the least of which is the problem of disposal of radioactive experimental materials.

Another technique discovered shortly after World War II is nuclear magnetic resonance. Although it was developed and first used in physics, it too has become a standard tool in chemical and biomedical research. As a consequence of a long series of advances in electronic and computer technology and in such seemingly unrelated fields as superconductivity, nuclear magnetic resonance technology has now developed to the point where isotopic species can be identified and the amount of a particular species present in a sample measured with high sensitivity and accuracy. These developments now make it possible to use stable but rare isotopes as tracers in chemical or biomedical experimentation. This eliminates the requirement for radioactive tracers and the radioactive waste disposal problems which accompany their use. But there is a significant drawback: the equipment required costs on the order of a half million dollars and requires skilled operators and sophisticated maintenance.

This example illustrates three common characteristics of evolving instrumentation technology: the opening of new opportunities, the trend toward greater complexity and cost, and the presence of trade-offs among advantages and disadvantages.

A second factor contributing to the present serious equipment situation is a combined effect of the constant or decreasing total research funding of the past decade, coupled with increasing numbers of qualified researchers generated by the post-Sputnik drive to produce more scientific manpower. Hopes that the funding crunch will abate some day soon lead researchers repeatedly to defer capital acquisitions in favor of sustaining research personnel.

The origins of the "equipment crisis," as some term it, are many and complex, and solutions to the problem will not be found exclusively in improvements in funding mechanisms. Still, the structure of the current system of funding mechanisms has contributed to the problem. The typical funding level of an individual research project does not accommodate acquisition of any but the most modest types of equipment. Requests for substantial items of equipment in a proposal for such a project are often the first element deleted in the inevitable paring of a requested budget to an awarded budget. Such deletions usually are favored by both agency program officers and by the peer reviewers on whose advice they rely. To a considerable extent, both groups are strongly influenced by the desire to provide at least partial personnel and operating support to all the investigators whose work receives high scientific merit ratings. This favoring of people over equipment is intended to preserve the vitality of new ideas and to ensure continuity in training the next generation of research scientists.

The compartmentalization of individual research projects makes difficult the pooling of funds from different projects or by several individual investigators to purchase equipment for shared use. In some cases, sharing is further inhibited by the inability of institutions to remodel and renovate space in which to co-locate research groups to facilitate equipment sharing. It should be noted that a recent national survey[3] of shared use of scientific equipment at colleges and universities revealed that more than 45 percent have either already established systems to facilitate equipment sharing or plan to do so in the near future.

Although NSF has programs in which funds are segregated specifically for equipment grants, these are sometimes criticized by the research community because funds so identified are viewed as taken from sources otherwise available for support of conventional individual research projects.

Where funds are made available for major instrumentation for shared use within an institution or on a regional or national basis, other problems arise. Rarely do either the government or the institutional grantee adequately project and provide for the costs of housing, maintaining, and operating major equipment acquisitions. Over the lifetime of a major instrument, such costs can easily exceed by many times the capital cost of the instrument.

Neither government agencies nor research universities now have policies and mechanisms for coping with the general, long-term need to maintain the national research equipment inventory against the inevitable inroads of obsolescence.

The "equipment problem" has been the subject of repeated studies and comments.[4] Additional studies are in progress. The relative reduction in investment in equipment by funding agencies and its impact on institutions have been reported. For example, a typical midwestern public research university reports that the ratio of equipment expenditures from federal research funds to total federal research fund expenditures dropped from 14 percent in 1963 to 10 percent in 1973 and 5 percent in 1978. During the same period, inflation and increased complexity of research problems to be solved severely taxed resources for equipment. An NSF survey[5] recently showed that the cost of scientific instruments in five basic science areas has increased fourfold since 1970. The investment required to equip new investigators is becoming a major problem. The universities' own resources have become too limited to provide what is needed. "Young investigator" grants usually assume availability of major equipment, and hence often seek an end without providing the necessary means. Furthermore, many highly sophisticated instruments require technical personnel to operate the equipment or supervise its operation and maintenance. Present mechanisms for distributing costs of such personnel are inadequate. They frequently depend on prior involvement and an overall commitment which fewer and fewer institutions will be able to make. This is a serious flaw in the short-term and discrete project system of financing basic research.

The problem is escalating in severity. A steady state system is needed in which replacement of worn out and obsolete equipment is structured into consideration of project costs.

Inadequate Provision for New Research Initiatives and for Sustaining Research Capacity

Current heavy reliance on individual research project funding creates gaps in the research support system. Universities are increasingly unable to fill these gaps. Cost effectiveness often dictates shared use of research facilities, and such facilities are often too large to be supported by any single project. It becomes the university's problem to provide such facilities, but the institution has little or no means other than *post facto* indirect cost recovery over a period of years. Frequently, unexpected needs or opportunities arise in ongoing investigations with no available funds to meet these needs. There may be a hiatus between grants where only institutional funds can bridge the gap. Young investigators need initial support to establish a performance record so that they can compete effectively in national competition. Established scientists occasionally change the direction of their research and need temporary support while they develop credibility in the new field. From time to time, new research areas emerge and appear promising, but until exploratory work can be accomplished there is no adequate basis for a proposal for project support. At present, institutional funds are likely to be the only source of support for such exploratory work or for any of the research capacity needs described above.

Research universities acknowledge that they have a responsibility to maintain an environment conducive to the research of their faculty. They devote substantial resources to this end in addition to the research support received from the Federal government. However, the sheer magnitude of the federally sponsored research effort at the major research universities, together with increasingly stringent restrictions on funds from other sources such as tuition and state appropriations, has put most universities in a position where they can no longer maintain an adequate research infrastructure without additional aid.

The present array of funding mechanisms provides inadequately for venture capital and research capacity maintenance. Institutional resources alone cannot meet the need. Deterioration of the productivity of the research enterprise may well be inevitable if the problem is not addressed. The NIH Biomedical Research Support Grant Program is one successful example which might be extended to other fields of research.

Erosion of Institutional Support for Research in the Humanities and Social Sciences

Traditionally, much of university research in the humanities and social sciences has been in basic research and of relatively small scale. The primary resources needed are often simply time for research, access to libraries and data sets, clerical support, research assistance, and publication support. Such research makes an important contribution to national life and to world understanding, but the magnitude of the needs of individual projects makes a highly centralized individual project support system, like the one which is used in supporting science and engineering research, cumbersome, inefficient, and costly.

At present this research is supported primarily by universities and private sponsors such as the foundations and to a limited extent the Social Science Research Council (SSRC) and the American Council of Learned Societies (ACLS). Some federal support is provided to SSRC and ACLS, but these organizations rely primarily on the foundations for support. Federal support is directed almost exclusively to large-scale projects and development of research materials and research resources, although a modest fellowship support program is available for research in the humanities. Several universities have established successful institution-based award programs for small-scale research. Some of these are targeted exclusively for the humanities.

Although the federal support of social science research as a fraction of total federal research and development support has remained essentially constant for a number of years, this support is not directed to small-scale research. Furthermore, a recent NSF review of this situation revealed a noticeable change in the distribution of federal social science research support among types of performer. Researchers in universities have received less of the support in recent years, while independent consulting organizations have received more. The character of the social science research undertaken with federal support also has changed, with a significant fraction now being highly targeted to address specific agency policy questions. These changes, therefore, increase the demand on universities and private sponsors for more general social science research support.

The present resources for small scale research in humanities and social sciences are quite limited. If adjustments are not made, the outlook for the future appears worrisome. Within universities, enrollment shifts away from the humanities and social sciences disciplines create pressures for resource reallocation to meet enrollment increases elsewhere. Economic pressures are severely taxing institutional capacity to maintain discretionary programs. Shifting federal support from the social sciences makes social science investigators in universities more dependent on institutional resources. Unmet research capacity maintenance problems combined with cost-sharing requirements in the system for support of research in sciences and engineering have become a serious drain on institutional resources and compete with institutional needs for supporting research in the social sciences and humanities.

The universities, the private sponsors, and the government will need to attend to these emerging problems.

Difficulties in the Funding Instruments

The funding instrument difficulties the Commission identified are of two types: difficulties with certain terms of the agreements and difficulties related to the underlying relationship between sponsor and performer.

Continuity and Stability

Continuity and stability are often missing. One of the most commonly perceived weaknesses in the present system is the lack of continuity. For maximum effectiveness, research projects must operate for a period long enough for serious accomplishment. Effectiveness can be impaired seriously if research is forced into short-term planning and funding cycles. In many basic research fields, annual or biannual renewal cycles are simply too short to permit acquisition of equipment and supplies, staffing for the research activity, and implementing the research strategy. Longer periods of assured support are vital. The National Science Foundation and the National Institutes of Health have been moving in the direction of better continuity by using grant periods which average two to three years. However, some agencies continue with one year support. Much of the time devoted to development and review of frequent renewal proposals is time diverted from performance of research. Where it is possible to design longer support into the system, the cost effectiveness of the whole enterprise can be improved.

Part of the continuity problem is associated with delays in renewal of support for ongoing programs. Such delays create funding gaps. When this occurs, either work must cease or support must be transferred from some other source. Universities commonly look to internal sources to underwrite the project temporarily, if eventual renewal of the project seems assured. At best, this leads to the burdensome paperwork of cost transfers to the renewed contract; at worst, it leads to non-reimbursement of costs incurred in the funding gap if the contract is not renewed or if it fails to include the gap within the new contract period or to authorize pre-award costs. On the other hand, if work were stopped and personnel dismissed when funding gaps occur, research progress would be significantly disrupted and delayed. It should also be noted that cost transfers associated with funding gaps are frequently at the root of accountability problems in the administration of research funds.

While some agencies are able to avoid funding gaps, many issue the formal notification of award only days before the effective date of the support agreement. This forces the research institutions to unfair and needlessly disruptive practices. Research personnel must be given more stability than such practices allow.

Surely improvements in continuity and stability are in order. Several mechanisms have been used in the past to provide such continuity and stability. These include: forward funding, roll forward funding, and step funding. Each is discussed below.

Forward Funding

The most straightforward continuity mechanism is multi-year forward funding. The original DOD Interdisciplinary Laboratory contracts in the early 1960s provided four-year funding. This had the advantage of assuring support long enough to acquire the personnel and the facilities to put the research project on a sound base. It had the disadvantage of removing flexibility from the funding agency for an extended period. Even two-year funding puts the research project on a base which is much more sound and likely to make possible much more progress than is the case with single-year funding.

Roll Forward Funding

In this mechanism full funding is guaranteed for a period of two or more years. On the basis of a favorable annual review, an additional year's funding is added to the end of the overall contractual period. In this way, the decision to extend support is always made at least one year in advance. This provides the principal investigator or the university an opportunity to plan ahead with assured funding for a long enough period to make effective management possible. The mechanism gives the sponsoring agency the ability to terminate projects in an orderly manner with ample warning to investigators and the institution.

Step Funding

Step funding is a version of roll forward funding which provides more flexibility for the sponsoring agency. Where this mechanism has been used it has typically provided full funding for one or more years, followed by two-thirds funding for the next year and one-third funding for the next following year. Each year the pattern is rolled forward one year maintaining the step feature. From the standpoint of the investigator or the university, a degree of funding for a substantial period ahead is assured. From the sponsoring agency's standpoint, continuity can be assured for three years, with the commitment of only two years' funds. If the sponsoring agency elects to terminate the project, the investigator and the institution have an extended period to terminate the work in an orderly fashion.

Flexibility

Flexibility is frequently inhibited. Unforeseen events often occur in research; new opportunities frequently develop in the middle of a research program. When such opportunities arise, it can be in the best interest of all parties to change direction in order to pursue the new lead. In basic research, the flexibility to alter direction is vital. In applied research and in development, research direction is usually somewhat easier to predict. In these latter areas, flexibility is still important, but is not as major an issue.

For the most effective research performance, such research changes must be accommodated with minimum delay and minimum friction between the project director, the sponsoring agency, and the institution. Some changes involve a renegotiation of the scope of work; others simply involve internal budget realignments. A number of persons in both the government and the universities believe that greater flexibility in the procedures on both sides is needed to facilitate such changes. While this is not entirely a problem of the funding instruments, some improvements in funding instruments may provide greater flexibility.

Another area in the post-award administration of sponsored agreements which needs improved flexibility involves cost transfers between related agreements. The compartmentalization of research support into multiple, discrete projects of limited duration may be advantageous for the selection of what research and which investigators to support. But it sorely complicates management of research funds, institutional planning, and research facility development. Cost transfers are an unavoidable consequence of the current system. The research program of a single investigator or group of investigators may be funded by several individual research support agreements, so that specific costs may be legitimately assigned to one or more individual accounts. Prudent management may require some retroactive reassignment of such charges. Agency program officials often are quite aware of the situation and recognize the validity of such adjustments among grants for related research. The present post-award administration procedures, however, make such adjustment burdensome in paperwork and require careful justification to avoid disallowance by auditors who tend to view all cost transfers as suspect.

Not all cost transfers are proper. Care must be taken to distinguish those which are legitimate and represent wise, intended use of public funds from those which are opportunistic. The critical element is a clear understanding about the scope of the intended purpose. If the purpose is defined too narrowly, the research productivity of the nation can be unnecessarily impeded. If it is defined too loosely, federal funds may be used for other than their intended purpose.

The problem of cost transfers to cope with funding gaps has already been described in the discussion of continuity and stability. Creative solutions to these problems which both fit the research process and assure appropriate use of federal funds will enhance research productivity and reduce the potential for actions which create negative audit findings.

Procurement Procedures

Procurement procedures are inappropriately used in research support. There is a widespread belief among university investigators and university research administrators that procedures and attitudes appropriate for procurement contracts are beginning to dominate sponsored agreements for basic research. They see clauses from federal procurement regulations designed for industry entering increasingly into agreements with universities. Even though clauses designed specifically for universities have been developed, industrial-type default clauses, stop work clauses, security specifications, and procurement-style reporting requirements are increasingly used in research agreements in what are perceived to be inappropriate ways. University scientists and administrators tend to believe that while contract administration in the various agencies was formerly done by scientists, now procurement specialists, trained in the procurement of deliverable products, are administering research contracts. The problem is seen as a particularly serious one in the case of solicited proposals where the Request for Bid provides all the contract language, and if the university raises an objection to the proposed terms, the bid may be viewed as nonresponsive.

On the agency side, the impetus to write tighter contracts appears to be a response to recent allegations of fraud, error, and abuse in university research operations. Undoubtedly, it is also an agency response to limited resources and perceived congressional and public pressure for agency responsibility.

The universities' concern is that the industrial model of tightly drawn advance specifications is gradually being imposed on an undertaking which can only realistically and successfully be pursued on a best effort basis. Much of the federally sponsored research in universities simply does not need and cannot thrive with the hard edge of the procurement policies and procedures

The universities, of course, do not have to accept contracts which they view as unduly restrictive. The procurement regulations specify a required core of clauses. To a certain extent contract clauses are negotiable, but the university risks losing the prospective research support completely if the negotiation is pursued too vigorously. At best, such negotiation on a contract by contract basis takes time and requires personnel, which increases administrative costs and impedes the progress of research.

As mentioned previously, the recently enacted Federal Grant and Cooperative Agreement Act of 1977 is intended to provide clarification for such matters. The implications of the Act in the management of federal assistance programs have been explored in a study mandated by the Act and conducted by the Office of Management and Budget (OMB). The final report of this study[6] became available just as the present Commission report was being completed. The Commission has consequently not had an opportunity to study it carefully and to comment on it in this report. We are hopeful that the Act and the study report will have a positive effect on sponsored research agreements between the government and the universities.

The Federal Grant and Cooperative Agreement Act makes clear that the distinction between "assistance" and "procurement" should be reflected in the type of funding instrument used. However, there is some concern in the research community that cooperative agreements as defined in the Act may become a common form of supporting basic research in the universities with the implication of much more widespread federal involvement in the conduct of the research. There is also concern that Department of Defense agreements will become more restrictive if that Department remains unwilling to use grants rather than contracts for support of basic research. One key to the problem is the development of a more widespread understanding and consensus about the nature and expectations of the grant relationship. In supporting research by way of grants, the government is *not* bestowing gifts, favors, or charity on institutions or individuals. It is building and renewing public investment in an important public asset. The government receives a valuable return for its investment.

Research grants are, for the most part, provided on a cost-reimbursement basis. As the Commission pointed out in its report on accountability,[7] despite differences in the nature and purpose of grants and contracts, both types of instruments are subject to the same set of cost principles. These cost principles were adapted from commercial cost principles and fit a procurement mode. The Commission recommended in its first report that accountability requirements be carefully tailored to the nature of the activity. It may well be that the most appropriate approach for grants for basic research would be for them to be offered on a grant-in-aid basis, rather than on a cost-reimbursement basis. Such an approach would shift the emphasis from analysis of costs and examination of documentation for validation of costs to evaluation of scientific efforts and results. The stringency of the review system for renewal of support and the relatively modest sums involved mean that such an approach represents very little risk to the university or the government. It could offer substantial savings in administrative costs.

There are several important issues involved in the choice of the funding instrument to be used. These include: who (the sponsor or the investigator) defines the research problem and objectives, whether the objective is to meet a need of the Federal government itself or to pursue a broader public purpose, the extent of federal involvement in or control over performance of the work, the congruence of the administrative requirements of the agreement with the nature of the activity, and the consistency of administrative procedures applied in federal programs. The universities, the researchers, and federal agencies tend to agree that these are the important issues, but they differ as to what is the overriding issue.

For the investigator and the university, the key issue is the congruence of the scope specificity and administrative requirements with the nature of the activity. For the federal sponsor, the key issue is whether the objective is to meet a need of the government itself or to encourage pursuit of a broader public purpose.

The challenge, therefore, is to develop funding instruments and a system of guidance for their use which can simultaneously accommodate the principal concerns of both sponsor and performer. The system must also be able to accommodate the wide variety among performers.

Cost Sharing

Diversity in cost-sharing requirements and differences in underlying rationale cause complications. The requirement for cost sharing in federal research grants to educational institutions is embodied in a provision in congressional appropriation acts for HEW, DOD, and the independent agencies:

> None of the funds provided herein shall be used to pay any recipient of a grant for the conduct of a research project an amount equal to as much as the entire cost of such project.

This requirement originally was introduced to replace statutory limitations on the amount of indirect costs educational institutions could recover. The intended purpose was to help assure efficient utilization of resources available and to promote sound planning and prudent fiscal policies.

Now almost fifteen years later, federal agencies differ significantly in how the cost-sharing requirement is imposed, what purposes it is intended to serve, and to what extent the institution must share in the costs. Some agencies provide for sharing on an institution-wide basis, negotiating institutional cost-sharing agreements. Others require documentation of cost participation on a grant by grant basis. Programs within agencies will also vary in the amount and purpose of the cost sharing required. For the National Science Foundation, the rule of thumb has been more than one percent cost sharing on research grants, but as high as 50 to 60 percent in equipment grant programs. In the NEH Research Division obligation varies from program to program, with minimum levels now ranging from 20 to 40 percent. NASA recently implemented a much less stringent interpretation of the legislative cost-sharing requirement based on discussions of legislative intent.

In recent years, spreading limited federal resources has emerged as a rationale for cost sharing. In some agency programs it seems to be the primary rationale. Cost sharing also serves as an "entrance fee" for participation in the federally sponsored research support system. In some cases, this entrance fee rationale slides into a form of cost competition. But true cost competition is not involved, since the competing proposals address not a single set of objectives but different, investigator-identified research problems.

These variations in rationale and requirements complicate the government-university research relationships and lead to some of the misunderstandings which are presently undermining its effectiveness.

In 1972, the Government Procurement Commission recommended to Congress that cost sharing be eliminated on research and development projects, except in cases where the performer of the project would clearly benefit, for example, through economic benefits or commercial sales. That Commission further recommended that the decision with respect to placement of research and development contracts or grants should *not* be influenced by potential involvement in cost sharing.

Later, in recognition of the costly and unproductive paperwork burden associated with documentation of cost sharing, the Federal Paperwork Commission reiterated the Government Procurement Commission recommendation to remove the requirement.

Despite these recommendations, cost-sharing requirements persist. Furthermore, the extent of cost sharing required seems to increase gradually, and the recently revised OMB Circular A-21 which sets out cost principles governing research awards imposes additional documentation requirements.

The question must be asked: Do present cost-sharing practices represent a wise approach for the support of research and for the health of the government-university relationship?

Indirect Costs

The administration of indirect cost reimbursement can be improved. A source of substantial strain within universities supported by federal research funds, and also more generally within the government-university research relationship, is the administration of indirect cost reimbursement. The indirect costs are real, the mechanism for computing indirect cost rates is spelled out in detail in OMB Circular A-21, and the rates which prevail are negotiated and agreed on by the university and the designated federal auditing agency. Nonetheless, many university researchers and federal program officers view university administrations' efforts to recover indirect costs as diverting research funds for purposes unrelated to research. The problem is exacerbated by indirect cost averaging on a university-wide basis. This puts a mathematician with little demand for overhead services on the same basis as the physicist with heavy demands for technical and other services which burden the indirect cost pool. While this problem is partly a university one, the Federal government in its administration of research funds can do more than anyone else to relieve the strain and to make the entire research effort run more smoothly.

In the National Institutes of Health, indirect costs are reimbursed separately from direct costs. Consequently, indirect cost reimbursements are normally not perceived to be in direct competition with direct research funds by investigators, agency program officers, and peer reviewers. The Commission believes that if other agencies, in particular the National Science Foundation, adopted the NIH approach to indirect cost reimbursement, substantial strain within the government-university research relationship could be eliminated.

Proposal Preparation and Review

Research manpower resources to prepare and review proposals are substantial and growing. One of the limitations of the individual project grant mechanism for support of research is the fact that considerable research manpower is required for the preparation and review of proposals. The research productivity cost of this burden must be considered. Various alternative mechanisms of support have been considered to reduce this cost and to meet other objectives. Some of these are now available, as described earlier in this document. The individual project system, however, has always enjoyed strong support among the investigators themselves. Several evaluations of the system have been undertaken over the years, with the principal result being an endorsement of the virtues of the system. The separately published results[8] of the Commission's review and discussions confirms that conclusion, but indicates that adjustments to that system should be made to reduce the effort consumed by proposal preparation and review. Recent federal agency moves to limit the length of proposals will help. Adjustments in the length of support period and streamlining the process for requesting continuation or renewal of support should also be explored.

Collaboration

Interdisciplinary and industry collaborative research need more effective approaches. While funding mechanisms and funding instruments are not the principal barrier to improvement of our capacity for effective interdisciplinary research and university-industry research collaboration, new concepts in funding mechanisms and instruments may be required to accommodate efforts toward these ends. Experimentation with new approaches offers the opportunity to explore and test the results.

Manpower Development

The close relationship of performance and manpower development justifies their linkage in research funding. Research experience has become an essential part of the education of students who will become scientists or scholars and also of many who will enter applied science or other research professions.

The involvement of students as research assistants on faculty research projects provides needed assistance to the faculty while giving valuable experience to the students. The value of research participation to students is enhanced when the projects address problems of high significance, as is often the case with federally supported research. The students provide a stimulus which enhances the research environment in universities. They represent a continuing flow of new minds. They bring questions, suggestions, challenges, and new ways of looking at data. Their thinking is not yet habitual. Their exposure to many new topics makes them able to see relationships and to draw analogies which experienced researchers can miss. Furthermore, the act of teaching by faculty members, whether in the classroom or in research supervision, forces reexamination of fundamentals and deepens the teacher's understanding.

Fluctuations in federal research support require an elasticity in the personnel pool which is partly provided by the availability of graduate students. Regular employees, such as research technicians, require a more stable employment structure and are not as adaptable to varying levels of support as are graduate students.

For all these reasons, therefore, the coupling of research and graduate education is clearly advantageous.

In addition to this substantive coupling, there is another facet of the symbiosis between research and graduate education which is related to funding mechanisms. Federal research training grants have the primary objective of developing research manpower, but they also contribute to research productivity through the trainee's research. Federal research grants have the primary objective of research performance, but also contribute to research manpower development through the participation of students as research assistants. It is therefore important that Congress, federal agencies, and universities recognize that adjustments in either of these mechanisms to address changing priorities related to their principal purpose will have impact beyond that immediately intended. They must also recognize the value and complexity of the symbiosis when issues of scientific and financial accountability are addressed.

University-Based Research Centers: A Growing Issue

In addition to the problems which the Commission has identified in the array of funding mechanisms and within the funding mechanisms themselves, attention should be drawn to a related issue which deserves more careful consideration from both the government and the research universities. This is the evolving role of university-based research centers in the national research enterprise.

For the most part, university scientists have combined teaching and research duties, with relatively few academic scientists working in purely research roles. With the decline in the size of the college age population and the consequent decline in the demand for teachers of science in the universities, academic job opportunities for young scientists inevitably will be limited for some time. This raises the question of maintaining the scientific research capability of our country at an adequate level in the face of potential declines in the capability of one of the current major performers and in the supply of young researchers.

There are several possible ways to deal with this issue. One way would be to shift more of the basic research burden to industrial laboratories, but this does not seem to be a likely possibility. With a few notable exceptions, industrial research and development laboratories have shown little interest in supporting or performing basic research.

Another way is to develop a series of research institutes outside the universities, sponsored by the Federal government, much as is done in West Germany. While this can be an effective means for accomplishing research, as the Germans have demonstrated, it divorces research from teaching. One of the advantages of the American system as it has been in the past is the close association of research with teaching and particularly with the teaching of graduate students. Not only is the scientific output of research scientists plus postdoctoral fellows plus graduate students greater than would be the research output of research scientists alone, but the system also produces the next generation of scientists in an effective apprenticeship setting. There has also been a substantial national investment in research facilities in the universities. It seems unwise to allow this investment to lie fallow.

A third possibility is the development of increased numbers of research institutes in university settings. This would keep research and teaching close together, with all the attendant advantages. However, a number of difficulties are already apparent in universities where such research institutes exist in significant numbers. They tend to result in the creation of a parallel-track staff of researchers who do not share the responsibilities and prerogatives of the regular faculty who teach and participate in university governance in addition to doing research. Counterproductive conflicts between these two classes of researcher can arise, as well as conflicts between the research institutes and disciplinary departments.

Another set of problems results from the necessity of developing administrative procedures for research institutes which in many ways differ from and conflict with the traditional decentralized administrative structures of universities.

The general question of how research universities can and should continue to play their role in the national research enterprise, in the face of coming economic and demographic strains, without sacrificing the structural characteristics which have been responsible for their past success, is a serious one deserving careful attention by both government and the research universities.

Conclusions

The Commission has studied the system of federal funding mechanisms used in the distribution of the nearly $4 billion per year supporting university-based research. It has examined the strains which appear to exist in this system in hopes of identifying modifications which will improve its effectiveness. On the basis of the Commission's interviews with many researchers and administrators from both the government and the universities, as well as its review of materials developed by others on this matter, the Commission has reached the following conclusions:

1. Essential Elements

For effective functioning of the research support system, the following key elements are essential:

- Fundamental agreement about the nature and purpose of the government-university relationship
- Diversity of sources, mechanisms, and instruments for research support and diversity of research performers
- Investment in both near-term and long-term objectives
- Provision for beginning new ventures and sustaining research capacity
- Continuity and stability of support
- Flexibility for effective technical and fiscal management
- Opportunities for new investigators
- Enlistment and training of future investigators.

2. Character of Agreements

Investigators, the universities, and the government need to develop a better understanding of the nature of the government-university research relationship and the purpose of the specific research agreements they make. The terms of such specific agreements must (a) contribute to the welfare of the relationship, (b) reflect the purpose of the agreement (whether procurement or assistance), (c) fit the nature of the activity to be undertaken, (d) call on the capacity of the recipient for responsible management of the activity, and (e) accommodate the diversity of the research performers and sponsors.

3. Unresolved Problems in a Basically Sound System

While the current system of research support mechanisms is basically sound, there are unmet needs which must be addressed and problems which need to be resolved. These include:

- A rapidly developing equipment inadequacy problem exists.
- Provision for new research initiatives and for sustaining research capacity is inadequate.
- Institutional support for research in the humanities and social sciences is eroding.
- Continuity and stability are often missing.
- Flexibility is frequently inhibited.
- Procurement procedures are used inappropriately in research support.
- Diversity in cost-sharing requirements and differences in underlying rationale complicate the government-university research relationship.
- Administration of indirect cost reimbursement can be improved.
- The fraction of the nation's research manpower resources being used to prepare and review proposals for research support is substantial and growing.

- Effective ways of approaching interdisciplinary research and collaborative research between universities and industry still need development.
- Complexity of the symbiosis between support of research and development of research manpower is not fully appreciated; nor have we yet learned how to control it successfully.

4. *Continuing Experiments*

Continuing experimentation with new and modified funding mechanisms and funding instruments should be encouraged to improve the research support system. The effectiveness of the system depends upon its adaptability to changing needs and a changing environment. The development and implementation of new concepts and new modes of research support therefore should be a permanent item on the agendas of federal agencies and the universities.

Examples of areas in which experimentation could now be useful include:

- Methods to improve the stability and continuity of support
- Ways to reduce the burden of proposal preparation and review
- Ways to increase research flexibility and reduce administrative costs.

5. *Mismatched Expectations*

In the government-university research relationship, a small number of unresolved issues is frequently the source of mismatched expectations and misunderstandings. Even though some of these issues may be clearly resolved at the policy level, they persist at the operating level. Examples of such unresolved issues include:

- The proper locus of control for the most effective basic research
- The extent to which support of research in universities is intended to serve the dual role of meeting research needs and developing research manpower
- How and why the universities and the government should share the costs of basic research.

6. *Complexity*

The government-university research enterprise is a complex, multi-faceted system. Unfortunately, few participants in the enterprise comprehend the whole system or recognize the extent of its complexity. It is easy, therefore, for its problems to be oversimplified and for the potential impact of their solutions to be misjudged. One example is the complexity of the relationship among the nature and balance among the funding mechanisms, research productivity, and the development of research manpower.

7. *A Forum: Refining the Concept*

In its first paper, *Accountability: Restoring the Quality of the Partnership*, issued in March 1980, the Commission presented a preliminary suggestion for a Forum of individuals concerned with the government-university research partnership. This was presented in a separate section of the report, entitled, "Toward Improvement: An Evolution." The separate presentation emphasized the view that the Forum concept related to all the work of the Commission, not only to accountability issues. The Forum would "see the relationship *as a whole*, and guide its evolution in directions that assure its strength and vitality." The Forum suggestion was offered to stimulate ideas and discussion. The proposal is:

> The Commission suggests the establishment of a new and independent Forum, as an experiment for five years. The Forum should provide a non-adversarial setting for persons from the public, Congress, universities, and federal agencies to watch over the government-university relationship and guide its evolution.

Since publishing this suggestion, response to the concept has come from many sources, including agencies, associations, the Congress, and universities. Most reactions are highly positive and strongly supportive. Considerable discussion as to the proper mission, locus, organization, membership, and activities of a Forum has begun.

The Commission is gratified with the character of this response, as it believes that broad and careful consideration throughout the government-university research community must precede the establishment of a successful body in response to its suggestion. In order to maintain and expand the dialogue on the Forum proposal, and to report the supportive character of the initial reaction, the Commission reiterates the suggestion in this report.

Based on these developments, the Commission concludes that further refinement of the Forum proposal should continue through discussion and appropriate actions by interested parties.

Recommendations

1. Equipment Obsolescence

The Commission recommends that the federal agencies and the universities adapt funding mechanisms and improve priority-setting strategies to solve the growing problem of research equipment obsolescence.

The Commission has considered the deteriorating research equipment situation. Steps must be taken soon to address this problem if the American research enterprise is to remain efficient and competitive internationally. Ideally, new funds would be appropriated to this end, but in a period of level or declining funding, there is no way to approach the problem without diverting a fraction of the funds presently going into support of people engaged in research activity. Undesirable as such diversion might be, the Commission believes it is necessary.

The responsibility for allocating the necessary funds falls on the universities, the government, and the scientific community. The universities can cope with this massive problem only in modest ways, but it is important for them to accept as much of the responsibility as possible. Federal agencies should place a clear priority on responding to well justified equipment requests through the regular funding mechanisms. This alone, however, will not be enough to halt the rapid deterioration of the national research equipment inventory. The Commission believes that for at least the next few years special supplementary measures will be necessary. Targeted equipment grant programs such as the ongoing NSF Research Instrumentation Program in chemistry and the recent one-time program in the National Institute of General Medical Sciences (NIGMS) offer models that should be adapted by other agencies.

Since the problem is so large, it is important to establish priorities among equipment needs. The knowledge and experience of the scientific community is essential to help the government and the universities establish priorities and to develop plans for equipment acquisition and use. The High Energy Physics Advisory Panel (HEPAP) and the Nuclear Science Advisory Committee (NUSAC) have played central roles in their fields in establishing national priorities for construction of large experimental facilities. Similar functions have been served by *ad hoc* groups in other fields, as in the case of the Dicke Committee in radioastronomy several years ago. These successful examples lead the Commission to suggest that such groups be established in other fields to advise the government and the universities on priorities among equipment needs and between equipment needs and other competing needs.

The government and the universities must develop incentives and strategies for effective sharing of equipment at both the local and regional levels. They must remove the obstacles to sharing which presently result from certain accountability requirements. They must also recognize that sharing of equipment can be constrained by the cost of renovation to provide co-location of users, by highly specialized use, and by the impracticality of transporting unstable experimental samples or auxiliary equipment to centralized or remote sites. Researchers must overcome their natural "territorial instincts" in acquisition and use of research equipment. It is especially important to include good cost-benefit analyses in the development of sharing strategies so that the advantages of sharing acquisition and maintenance costs are not overshadowed by administrative and operating costs.

Because it is so important to divert the minimum possible amount of money away from current research support to equipment acquisition, imaginative funding devices also are called for. Consideration should be given to debt financing ("mortgages"), with retirement of the debt and interest through use charges to sponsored projects.[9] We believe that research supporting agencies should make clear to investigators, peer reviewers, and universities the acceptability of equipment use charges. These charges would allow timely acquisition of important pieces of equipment while distributing the cost over a convenient time period. In certain situations, particularly in public institutions, it may be possible to promote issuance of revenue bonds. Revolving lines of credit at banks or outright loans may be appropriate. Lease or lease-purchase arrangements offer other alternatives for facilitating equipment acquisition.

Substantial interest charges will characterize many of these approaches and, while reimbursement of interest charges can now sometimes be negotiated in occasional cases, revision of OMB Circular A-21 to permit routine reimbursement of interest charges would greatly facilitate the debt-financing approach to the equipment problem.

2. Stability, Continuity, and Flexibility

The Commission recommends that Congress and the federal agencies develop and implement means to increase the stability, continuity, and flexibility of research support while retaining the capacity to respond to changing national priorities. The Commission offers several specific recommendations to this end.

Basic research is a relatively long-term enterprise, characterized by cumulative building on previous work in the same or related fields. While the continuing opportunity to initiate new basic research projects is an essential element in the overall national research program, changes in national needs have far more impact on applied research and development directions than on basic research. For this reason, provisions for the continuity and stability which enhance basic research productivity can be implemented with little or no cost in overall program flexibility.

Duration of assured support is one critical factor for research planning. Frequent competitive review in basic research is often unnecessary. It diverts investigator efforts from active research to proposal writing and review. It complicates the long-term planning by both the investigator and the institution which is necessary for the wise use of resources, facilities, and personnel.

Some agencies, notably NSF and NIH, have designed mechanisms to provide multi-year grants so that research is subjected to the full competitive review process only every two or three years. Some agencies, however, continue to make only one-year awards even where the actual turnover among supported investigators is small. For some agencies, the limitation to one-year awards is based on the one-year congressional appropriation cycle and the agency experience of considerable fluctuation in the magnitude of funds appropriated for basic research. Therefore:

(a) The Commission recommends that Congress consider making a transition to a two-year appropriation cycle for those agencies and components of agencies which support basic research.[*]

Further:

(b) The Commission recommends that those agencies and components of agencies which support basic research lengthen the average duration of their basic research support agreements to at least two and preferably three years, if they have not already done so.

Also:

(c) The Commission recommends that agencies experiment with authorizing program officers to award a limited number of non-renewable extensions of support at approximately the same level, without the full renewal proposal submission and peer review.

Such extensions would be reserved for those projects which (a) are natural extensions of the previously approved project, (b) are progressing well, and (c) need continuing support. In such cases full competitive review is an unnecessary diversion and wastes the resources of the government, the university, and the researcher.

Another critical factor for research planning is the extent of advance notice of decisions on future research support. In the course of its work, the Commission has encountered many reports of delays in notice of renewal support for ongoing research, notwithstanding that renewal proposals were submitted on time and well before the end of the grant period. Some delays are extensive, lasting weeks and even months after the end of previous award periods. The Commission also learned that notices of new awards and of renewals or nonrenewals are often received within days of their effective dates, thus allowing little or no time for orderly planning. Delayed or inadequate notice of decisions on future support imposes serious burdens on performing institutions and researchers. It forces institutions to underwrite federally sponsored research programs without assurance of eventual reimbursement or compensation for foregone interest on the capital advanced, and it slows initiation of new projects.

This problem sometimes results from delays in the congressional appropriations process. To some extent, short lead times in notices of support decisions are a result of efforts to minimize the time between the submission of a proposal and the initiation of the work. This is clearly the case where an external peer review process is used. However, a significant part of the problem appears to be due simply to administrative inadequacies in the agencies.

For individual research project grants or contracts, an average duration of two to three years of support would allow reasonable stability, provided it is coupled with an adequate, advance notice of the decision on future support. Therefore:

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[*] Federal agencies typically operate on a one-year appropriation cycle. Most agencies must expend their funds in the year for which they are appropriated. NSF funds are available for expenditure for a two-year period. This extended availability does not contribute as significantly to a solution as would a biennial cycle.

(d) The Commission recommends the introduction of incentives for funding agencies to provide more timely notices of awards.

The Commission offers two specific suggestions: (1) three-month extension of research support at the same level would be provided to continuation or renewal proposals if the principal investigator meets the agency deadline and the agency fails to provide notice of the funding decision at least thirty days prior to the end of the current award period; (2) imputed interest costs would be allowed for use of institutional funds to continue a project for which the agency award is so delayed.

(e) The Commission recommends that agencies which fund large research programs build in forward-funding mechanisms or devise new ways to cushion the impact of termination of support.

For individual research project grants or contracts an average duration of two to three years provides reasonable stability. While nonrenewal of support for such a project is always disappointing, the impact is usually quite localized. Nonrenewal of support for a large research program grant or a center grant, however, has a significant impact on both individuals and the institution and requires considerable advance planning. Special mechanisms to provide adequate lead time for an orderly phase-out are necessary to limit destructive disruption. Such mechanisms have been used successfully by federal agencies in the past. For example, NASA and DOD have used the step-funding and roll-forward funding mechanisms to good advantage.

3. Research Capacity and Initiatives

The Commission recommends that the government and the universities work together to develop or adapt a funding mechanism to sustain the research capacity of universities, especially their capacity to undertake new research initiatives.

A responsibly managed research enterprise, whether at the national or the institutional level, must provide for sustaining research capacity and for seed money to support new research thrusts. Although the present system of mechanisms for funding university research is supple and diverse, it fails to provide adequately for these needs. The Commission recommends that the government and the universities together remedy this lack.

The present heavy reliance on individual research project support in the government-university research enterprise encourages and often demands a rather fine grained compartmentalization of both scientific effort and funding. This, in turn, leads to voids and discontinuities in the funding available from external sources to a research university, to the detriment of smooth and efficient functioning of its research effort. For example, pilot projects must often precede project support. Emergencies and unexpected opportunities arise. Facilities need updating for contemporary research purposes. New investigators must get their research programs launched. Shared research resources must be developed and maintained throughout the ebb and flow of external project support. Provision for these costs is rarely made available through the regular funding mechanisms.

In the past, when the magnitude of the total research effort of the research universities corresponded to a relatively small fraction of their budgets and they were less burdened by financial pressures than they commonly are now, universities frequently found it possible to compensate for these voids and discontinuities from their own funds, as a natural part of meeting their responsibilities for support of research. Today the institutions' capacities fall far short of meeting the needs associated with their greatly increased participation in federally sponsored research. Furthermore, the gap between these needs and the university capacity to meet them is growing. The research programs of a typical research university require tens of millions of dollars annually and may account for a quarter of the institutional budget. At a time when all sources of institutional income are severely restricted, it is extremely difficult for a research university to find the resources to fill substantial voids left by current federal funding mechanisms. This burden lies heaviest on those institutions with the largest commitments to the government-university research partnership.

What is needed is a funding mechanism which can serve as a kind of balance wheel to keep a university research effort functioning efficiently despite the irregular and fluctuating forces caused by other funding mechanisms. We have chosen to label this new mechanism "research capacity support," although other terms would be equally appropriate. We envision a mechanism which would provide funding at a level related to the total federal research and development funding of the institution. Coupling the level of research capacity support to the total federal support provides a tie to the existing quality assurance and selection processes and a connection between need and response. The level of support should probably lie in the range of one to three percent of total federal research support. The analysis required to establish the appropriate level was beyond the resources of the

Commission but will need to be undertaken. Because decisions about the needs to be addressed and priorities among them can adequately and perhaps optimally be made at the local level, research capacity support funds would be allocated by the institution for purposes consistent with general principles established by the Federal government in consultation with the research universities. These principles should include:

1. Research capacity support funds would be used to meet research needs which cannot adequately be met through other funding mechanisms.
2. The distribution of research capacity support among research fields should correspond generally to the pattern of federal research support provided the institution through other funding mechanisms.
3. Allocation of research capacity support funds would emphasize maintenance of research capacity through, for instance, provision of equipment or facilities for shared use by many investigators, and provision of venture funding for new research undertakings.
4. The allocation system would be designed by each institution to suit its own structure, but should meet general quality assurance and accountability standards established by the government in consultation with the research universities.

This research capacity support mechanism should include a provision for demonstration of the institutional commitment to research through a requirement that the federal funds be supplemented by a significant allocation of institutional funds; something on the order of 10 percent of the federally provided research capacity support funds would seem appropriate. It should be pointed out that this institutional participation would also be responsive to government interest in institutional cost sharing. The research universities have long pressed for elimination of cost-sharing requirements imposed by the Congress and by the agencies, not because they oppose cost sharing *per se*, but because they oppose the administrative burden which accompanies these requirements under present systems. Institutional participation in research capacity support funding would constitute substantial cost sharing in a simply documentable fashion.

The Commission wishes to emphasize that it does *not* envision that the creation of a research capacity support mechanism will necessitate "add-on" appropriation of funds over and above normal federal research funding levels. It recognizes that the ability of the Federal government to support research in universities is and will continue to be severely constrained, and the use of such a new funding mechanism can most likely occur only at the expense of other mechanisms. Under current economic conditions, such a mechanism is needed to help universities plan and manage their research efforts. This would allow universities to provide the best research possible with the available funds, maximizing efficiency and minimizing administrative and overhead costs.

4. Assistance As the Predominant Approach

The Commission recommends that the Federal government and the universities adopt the policy that assistance rather than procurement is the appropriate mode for support of university research, except where unusual circumstances specifically justify the use of the procurement mode.

The Federal Grant and Cooperative Agreement Act (Public Law 95-224) distinguishes two modes of federal funding for work performed by non-federal organizations, assistance and procurement. It further defines three types of funding agreements, *viz.*, grants, cooperative agreements, and contracts. The Commission views this Act as one starting point for evolving a better system of funding mechanisms for support of university research and development. In university research, it is important to recognize that activity labels such as "basic research" or "applied research," and funding instrument labels such as "grant," "cooperative agreement," and "contract" should not themselves be the determining factor for the choice of the terms of the agreement.

For the researcher and the university, the key issue is the congruence of the specificity of the scope of the agreement and of administrative requirements with the nature of the activity. For the federal sponsor, the key issue is whether the objective is to meet a need of the government itself or to encourage pursuit of a broader public purpose.

The challenge, therefore, is to develop funding instruments and a system of guidance for their use which can simultaneously accommodate the principal concerns of both sponsor and performer. Such a system must also be able to accommodate the wide variety among performers.

The Commission believes that, for almost all university research activities, assistance rather than procurement is the appropriate support mode. Inappropriate use of procurement procedures creates unnecessary misunderstandings and administrative difficulties for federal agencies and universities alike. This Commission recommendation would require that funding mechanisms used to support university research be tailored to the assistance mode rather than the procurement mode, except in cases where the specific circumstances clearly demand the procurement mode. In other words, selection of the procurement mode ought to require a conscious decision based on explicit justification.

This recommendation is corollary to Recommendation 2a of the Commission's first report on accountability, which calls for development of a "new system for accountability tailored to the nature of the activity being sponsored and based on a set of minimum core requirements applicable to all research agreements. The core requirements would be sufficient for all basic research. Further requirements would be added only for activities of a pronounced procurement character."

5. Experimentation with Mechanisms

The Commission recommends experimentation with new concepts in funding mechanisms as the government-university research relationship evolves. In particular, the Commission recommends experimentation with grants-in-aid managed at the local level.

One objective of the Commission in making this recommendation is to reduce administrative complexity and to focus emphasis on scientific accountability as opposed to excessively detailed fiscal accountability. The extraordinary care given to the selection of research projects to be funded, and the critical role which past performance plays in decision for renewal of support, provide a reliable test of scientific accountability, and provide a good opportunity to experiment with alternate fiscal accountability approaches. In the Commission report on accountability, Recommendation 8 calls for delegation of more authority to the universities for budget and management decisions under sponsored agreements.

The Commission urges experimentation with another approach to the same problem, *viz.*, use of grants-in-aid. This would be an award made in response to a normal research proposal including a detailed budget like the current NSF and NIH proposals, but with the accounting to the Federal government limited to scientific reporting, and with the fiscal management delegated to the investigator and his institution. The Commission believes that the incentives for wise management of resources which are inherent in the research funding system reduces the risk of fraud, abuse, or inefficiency to a minimal level.

We suggest that the experiment be designed to test this approach in different institutions and in different research disciplines, beginning at modest support levels and increasing support if the experiment proves successful.

The Commission recognizes that such an approach shifts the locus of budget control from the government to the university and that this shift may introduce intra-university strains. The Commission believes, however, that such strains can be minimized by careful cooperative planning and that the advantages of increased flexibility and reduction in administrative burdens will outweigh any residual difficulty.

The Commission recognizes that this new mechanism might require some adjustments for the calculation of indirect costs, but we believe these will be modest and manageable. The Commission Recommendation 5 in its accountability report for a "standard deduction"—an optional method of deriving the indirect cost component for faculty indirect cost activity—removes a barrier which previously thwarted experimentation with the grant-in-aid approach.

6. Cooperation within Institutions

The Commission recommends that the universities and the government seek ways to promote intra-institutional cooperation in all aspects of research operation. The Commission offers some specific recommendations toward this objective.

There are several ways in which the present government-university research system tends to pit research scientists against their own institutions and to work against cooperation within the institutions. The heavy use of the individual research project support mechanism, for all its strengths for selection of research, has some disadvantages. The combination of its dependency on individual entrepreneurship with its compartmentalization of research support can lead investigators to resist sharing of equipment and other resources. The inability of the universities to provide from their own resources the research equipment and facilities commensurate with the present level of their research activities places the federal agencies and their project officers, instead of the institution, in the role of primary sponsor. Agency program officers occasionally circumvent the government-university contractual relationship and attempt to negotiate directly with the principal investigator on matters which are an institutional concern. These circumstances produce divided loyalties, introduce friction between the investigator and university administrative officers, and undermine the stewardship capacity of the institution. Accountability problems can result from these strains.

The Commission repeats in this report one of the recommendations made in its report on accountability:

(a) The Commission recommends that Congress authorize and the agencies develop arrangements for aggregating research projects for post-award administrative purposes.

Implementation of that recommendation would address a number of current problems, including the problem of arbitrary barriers to sharing costs among related projects and disincentives for intra-institutional cooperation. The aggregation the Commission proposed would preserve fully the appropriate control for the principal investigator.

(b) The Commission recommends that the universities make concerted efforts to reduce internal friction and misunderstanding about indirect costs through education and full discussion of issues.

A major source of friction between investigators and their institutions is the use of federal funds to reimburse a portion of the university's indirect costs. Many institutions have failed to provide adequate information to their research personnel about the nature of indirect costs and the relevance of these charges to the conduct of research. Even where such information has been provided, some investigators continue to believe that such reimbursement represents undeserved "profit" by the universities. Others believe that the averaging method used in distributing indirect costs among projects represents an unfair tradeoff between the cost of more precise accounting and the inequities inevitable in the use of an averaging approach. These concerns not only affect intra-institutional relationships but also influence the thinking in the peer review groups which help select the research to be funded.

(c) The Commission recommends that the method used by the National Institutes of Health for reimbursing indirect costs be adopted by NSF and other agencies which interact significantly with universities.

Since attitudinal change is not a rapid process, some more immediate measures to reduce unnecessary strains seem wise. Under the NIH method, funds are specifically earmarked for reimbursement of the indirect costs of research at the agency level and are segregated from funds for support of the direct costs of research. The funds which are granted for a specific research project then are not immediately influenced by the magnitude of the indirect cost rate or a change in that rate. This decoupling of indirect cost considerations from direct cost considerations is also helpful because it reduces the temptation to make meaningless or misleading comparisons of the indirect cost rates of different institutions.

7. Cost-Sharing and Matching Requirements

The Commission recommends that Congress, the agencies, and the universities reexamine the rationale for cost-sharing and matching requirements in federal programs for support of research in universities to assure that any such requirements are constructive in furthering the mutual objectives of the government-university research relationship.

Formal statutory requirements for cost sharing on research grants were introduced in the mid-1960s when the arbitrary ceiling on indirect cost recovery was removed. The rationale presented then was that such cost sharing would serve as an incentive for wise choices on which research to undertake, for efficient [illegible] ation, and for cost control. Such cost sharing was also considered appropriate since research is one [illegible] niversity's regular functions.

As the number and kind of federal programs supporting research and other activities in universities has increased and as the federal programs providing support for activities of state and local governments have grown, expectations and demands for cost sharing or matching have grown and changed. Practices used in one program have been adopted in other programs. In some programs, the principal rationale seems to be to help establish priorities among applicants by testing the grantees' relative commitment, as evidenced by cost sharing. In some programs, the primary impetus for the cost-sharing requirement is to stretch limited federal resources to respond to more applicants. In some programs, the program objective and responsibility for meeting it are shared, and cost sharing reflects this mutuality of interest. In other programs, the cost-sharing requirement is intended to serve as an incentive to stimulate the private sector to provide support. In some situations, however, cost sharing seems to be simply an "entrance fee" to participation in the government-university research relationship. The variation in rationale and requirements for cost sharing complicate the government-university research relationship and undermine its effectiveness.

The Government Procurement Commission recommended elimination of cost sharing from research and development projects except in cases where the performer would clearly benefit, for example, through economic benefits or commercial sales. That Commission further recommended that the decision with respect to placement of research and development contracts or grants should *not* be influenced by potential involvement in cost sharing. The Federal Paperwork Commission reiterated the Government Procurement Commission recommendation because of the costly and unproductive paperwork burden associated with documentation of cost sharing. Despite these recommendations, the requirement persists, new documentation requirements have recently been added, and the amount of cost sharing required seems to be increasing.

In its first report on accountability, the Commission urged Congress to remove the statutory requirement for cost sharing so that the burden of documentation could be removed. The Commission recognized that whether or not there is a statutory requirement, universities and the government will continue to share the costs of basic research.

The Commission also recognizes that it will be increasingly tempting for federal agencies to try to spread resources by requiring greater cost sharing. The resiliency of the universities is greatly diminished and cannot support such demands. Therefore, Congress, the agencies, and the universities need to reexamine the rationale and requirements for cost sharing in federal programs for support of research in universities to make sure that only constructive and necessary requirements are imposed.

8. Additional Science Indicators

The Commission recommends that the Office of Science and Technology Policy and the National Science Foundation (a) develop, employ, and report additional science indicators which reflect the balance and diversity of federal research funding programs and (b) encourage the general use of these indicators in research policy development and planning by government and universities alike.

The Commission has studied the range of existing research funding mechanisms, from individual research project grants to large block grants and institutional grants. It has considered the spectrum of federal funding agencies and the range of research styles from what is known as "little science" to "big science." It is convinced that the diversity of funding mechanisms and agencies which now exists in the United States is a crucial element in the strength of American science. It judges that the present balance among agencies and mechanisms and between little science and big science is not dangerously far from optimum. However, the Commission also recognizes that the degree of diversity and the conditions of balance depend on scientific, economic, and political circumstances, and therefore vary with time. A proper awareness of these factors is essential to government and university policy makers.

The Commission does not consider itself to be in a position to suggest which way the present balance might be shifted. It does believe that more diversity would be far preferable to less. But most of all, the Commission stresses the importance of a general awareness of the state of balance and diversity in the government-university research relationship. This will require information and indicators which reflect the distribution of federal research support across the many different types of funding mechanisms and the variation of the distribution with time. Table I of this report is an example of such an indicator. These should be developed at a national aggregate level and also within individual scientific fields and within federal agencies. Such distributions can be useful indicators of evolving national research policies. These indicators are not commonly available at present.

9. Growth of Research Centers and Institutes in Universities

The Commission recommends that the research universities, individually and collectively, examine carefully the implications for university development, structure, and governance of the growth of university-associated research centers and institutes.

The research universities of the nation face many difficult questions as they confront the financial and demographic realities of the remaining two decades of the twentieth century. Among these is the question whether the universities will find it desirable or possible to maintain their positions as the principal performers of basic research within the national research and development enterprise. This is also a crucial question for the Federal government. If the universities' contributions to the national research effort were to wane while national requirements for research continued to be strong, the government would need to turn to other performers. There are many good reasons why the universities should strive to maintain their capabilities as research performers. There are also cogent reasons to believe that if they are to succeed in doing so, they may need to make some fundamental adjustments in their character. For example, federally funded research and development centers staffed by non-faculty researchers may become much more prominent features of research university campuses than they now are. If this occurs, new conflicts and pressures will surely arise within the universities to develop the role of non-faculty researchers in the university governance structures.

The Commission believes that few universities have given adequate consideration to the possibilities posed by such questions and strongly recommends that they do so. We suggest that the major university associations establish a task group to examine the issues, and that consideration be given to organizing a workshop or conference on the subject to encourage widespread discussion and planning within and among research universities.

Appendix I: References

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4. See, for example:
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8. National Commission on Research. *Review Processes: Assessing the Quality of Research Proposals*. (Washington, D.C.: National Commission on Research, May 1980).

9. Olson, George G., Vice President for Research, Colorado State University. Private communication, 1980.

Appendix II: Sources

The Commission is indebted to the many persons who have provided information and advice, and it wishes to acknowledge its appreciation for their efforts. Invited expert witnesses have testified on the issues within the Commission's purview at its monthly meetings; open hearings have been held on five university campuses; subcommittees have met with individuals and groups from the Federal government; and members and staff have attended or made presentations at meetings and hearings convened by educational associations, government agencies, and Congress.

Witnesses. The following individuals presented views and gave assistance in the development of this document. The Commission wishes to emphasize that the views in this document are its own and not necessarily those of the listed individuals. This list includes meetings through March 1980.

Richard Atkinson, Director, National Science Foundation
James M. Banner, Jr., American Association for the Advancement of the Humanities
Robert Barlow, Cornell University
Carl P. Blakley, Department of Energy
Robert M. Bock, University of Wisconsin
Howard W. Bremer, University of Wisconsin
Newton Cattell, Association of American Universities
Honorable Lawton Chiles, U.S. Senator from Florida
Robert Coakley, U.S. Senate Subcommittee on Federal Spending Practices and Open Government
Tom Collins, University of California, Los Angeles
Theodore Cooper, Cornell University
Lawrence G. Crowley, Stanford University
Robert Cutler, National Science Foundation
John M. Deutch, Under Secretary, Department of Energy
Sidney Drell, Stanford Linear Accelerator Center
Marvin E. Ebel, University of Wisconsin
Anthony Egginton, British Science Research Council
Gretchen Engquist, U.S. Senate Subcommittee on Health and Scientific Research
Gary Evans, Department of Agriculture
Kristine Forsberg, Department of Energy
Osmund Fundingsland, General Accounting Office
George Gamota, Department of Defense
Howard Gobstein, General Accounting Office
Delphis C. Goldberg, U.S. House of Representatives Subcommittee on Intergovernmental Relations and Human Resources
Milton Goldberg, Council on Governmental Relations, National Association of College and University Business Officers
James Haas, Council on Library Resources, Inc.
Robert W. Hougas, University of Wisconsin
Richard F. Kaufman, U.S. Congress, Joint Economic Committee
William Kays, Stanford University
Bryant Kearl, University of Wisconsin
Charles V. Kidd, George Washington University

Richard M. Knapp, Association of American Medical Colleges
Philip Kropatkin, Deputy Director, Audit Agency, Department of Health, Education, and Welfare
James Ling, Department of Energy
John Lordan, Office of Management and Budget
David Mears, University of California System
Richard Meserve, Office of Science and Technology Policy
George Millburn, Department of Defense
Bryan Mitchell, Assistant Inspector General, Department of Health, Education, and Welfare
Thomas Morgan, Association of American Medical Colleges
Morton Myers, General Accounting Office
Robert Newton, National Science Foundation
Donald Nutter, U.S. Senate Subcommittee on Health and Scientific Research
George G. Olson, Colorado State University
Gilbert S. Omenn, Office of Science and Technology Policy
George Pake, Xerox Corporation
J. Thomas Parmeter, Michigan State University
Michael Pelczar, Council of Graduate Schools of the U.S.
John D. Phillips, National Association of Independent Colleges and Universities
George Pilarinos, National Aeronautics and Space Administration and National Science Foundation
Dennis Prager, Office of Science and Technology Policy
Frank Press, Office of Science and Technology Policy
William F. Raub, National Institutes of Health
Jerold Roschwalb, National Association of State Universities and Land-Grant Colleges
Halsey L. Royden, Stanford University
Jack Sanderson, National Science Foundation
Reilly Schaefer, University of Wyoming
Helen Schroeder, National Institutes of Health
Reagan Scurlock, Council on Governmental Relations, National Association of College and University Business Officers
Richard Sessions, University of California, Los Angeles
Irving Shain, University of Wisconsin
Philip Smith, Office of Science and Technology Policy
Donald Speer, National Science Foundation
Elmer B. Staats, Comptroller General of the United States
Richard E. Stephens, Department of Energy
Eldon Taylor, Inspector General, National Aeronautics and Space Administration
Richard Tropp, Environmental Protection Agency
Thomas van der Voort, U.S. Senate Committee on Appropriations
David Wilson, University of California System
Raymond Woodrow, formerly of Princeton University

Agency Liaison. These persons have been appointed by their agencies:

Salvatore Cianci, Alcohol, Drug Abuse, and Mental Health Administration
George P. Millburn, Department of Defense
Richard E. Stephens, Department of Energy
Osmund Fundingsland, General Accounting Office
Walton Francis, Department of Health, Education, and Welfare
James R. Lawson, National Aeronautics and Space Administration
William F. Raub, National Institutes of Health
Jack Sanderson, National Science Foundation
Eliot R. Cutler, Office of Management and Budget
Philip M. Smith, Office of Science and Technology Policy

Open Hearings. Over seventy persons testified before the Commission during hearings at the national conference of the American Association for the Advancement of Science and on the campuses of the University of Alabama, Birmingham; California Institute of Technology; Stanford University; the University of Wisconsin, Madison; and the University of Utah with the Inter-Mountain University Research Association. A number of these speakers presented views on funding mechanisms in addition to other topics under consideration by the Commission.

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